Scaffolding Learning

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Keywords

Argumentation; Calibration; Fading; Learning progressions; Science learning; Zone of proximal development

Definition of Scaffolding

Wood et al. (1976) were the first to use the term *scaffolding*. Within a tutoring context, Wood and colleagues described scaffolding as involving support such as reducing the degrees of freedom available to a learner, emphasizing relevant features of a task, and modeling solutions to a task. They demonstrated how, with this support, children were able to attain higher levels of performance than they could without the scaffolding. In essence, then, scaffolding works as a mediator within a learner's zone of proximal development (Vygotsky 1978). Stone (1998) identified key features of face-to-face scaffolding interactions, including careful determination of the task, accurate diagnosis of the learner's current level of proficiency and calibration of support to match that level, providing a range of types of support, and fading the support over time. Others have argued that scaffolding can be instantiated through physical artifacts or software features that serve as cognitive tools that mediate action. Scaffolding can serve to reduce learners' cognitive load and provide expert guidance. The result of scaffolding in learning environments is that learners become more able not just to accomplish the task with support but also that they learn from the process and improve their future performance.

Scholars have expressed concern, over the last decade or two, that "scaffolding" has been used so broadly and with such limited precision as to have become equivalent in many people's minds with any form of instructional support. These scholars argue that the elements of *calibration* and *fading* are critical in describing a form of instructional support as scaffolding.

Importance of Scaffolding in Science Classrooms

Why is it important to consider scaffolding in science learning environments? In short, it is important because with scaffolding, learners can engage in more sophisticated tasks than they can engage in without support, thus making their learning both more effective and more efficient. Even young children are able to engage in sophisticated scientific practices and learn complex science concepts when provided with strategic

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

scaffolding (Metz 1995). Similarly, while high school students are unlikely to learn complex content or engage in challenging investigative practices on their own, with scaffolding, they can do so. Recognizing these capacities is increasingly important as many nations move toward setting more ambitious science education standards. Scaffolding meaningful learning of science content and practice promotes relevance and integration, thus minimizing the development of inert knowledge.

Scaffolding can promote students' (a) learning of core disciplinary ideas, (b) engagement in scientific practices, (c) understanding and application of crosscutting concepts, (d) involvement in processes and procedures expected in a classroom, (e) collaboration, and (f) metacognition and reflection. Examples of scaffolding – for example, for the scientific practice of argumentation and explanation construction – might include teachers' discourse moves (e.g., regularly asking students for evidence to support their claims until doing so becomes part of the regular classroom discourse), written prompts in print curriculum materials (e.g., hints or prompts for how to write such evidence-based explanations that fade over the course of a unit or a year), or features in software tools (e.g., guides, graphic organizers, or other features that allow students to match evidence with claims and capture in-process thinking). Scaffolding can also be provided via other physical artifacts in a classroom or other learning environment (e.g., posters with inscriptions in a classroom or features provided via handheld devices to be used in museum settings).

While many tend to think of scaffolding as serving a mainly structuring capacity – through reducing the degrees of freedom, for example, or providing additional information or guidance – in fact, effective scaffolding also, in a purposeful manner, increases the complexity of tasks (and then supports learners in accomplishing the new, more complex tasks). One example would be when students are asked to generate artifacts that reflect the disciplinary practices of science (e.g., through supporting claims with evidence and reasoning or through distinguishing observations from interpretations). A second example would be when students are asked at key junctures to reflect on their engagement in a task, rather than proceeding without sufficient mindfulness. In these instances, scaffolding serves to make learning more complex, thus increasing the potential for learning, especially in the long term.

Science Teaching and Learning Implications

One complex area of focus within research on scaffolding is the notion of fading. Fading can refer to changes in the character, amount, or level of support being provided and leads to the learner taking increasing responsibility for the task. Investigating how to fade scaffolding in a science classroom context has been notably challenging. Instructionally, fading might occur in one of at least three ways. The teacher might fade scaffolding for individual students, based on individualized diagnosis and calibration (much as a tutor might fade scaffolding for an individual tutee). Curricular materials might fade scaffolding over a sequence of weeks or months, based on curriculum developers' hypotheses about student learning and progress vis-à-vis instruction; such fading, though, would be at the class level, rather than at the individual level. Finally, software might fade scaffolding over time, based on data collected on individuals or small groups of students. (Progress is being made in the technological capacity to do this effectively.) These different instructional instances reflect differences in how learners' strengths and struggles are diagnosed as well as how support is calibrated and adapted. Studies demonstrate that learners who experience well-faded scaffolding over time can be successful in unsupported variants of the tasks. In fact, some studies have identified positive learning effects of purposefully fading scaffolding within print curriculum materials, providing at least an existence proof that such fading does not necessarily need to be individualized to be effective. Current work on learning progressions may inform with more precision when scaffolding can likely be effectively faded.

Different agents (e.g., teacher, curriculum materials, software tools, peers) can scaffold science learning. The efficacy of supports provided via curriculum materials or software tools is enhanced by support provided by teachers. Teachers, curriculum materials, software tools, and peers can all provide different kinds of scaffolding (e.g., generic and content-specific; process-focused and rationale-oriented) that work synergistically, or they can provide redundant scaffolding that serve to reinforce one another. Student learning is enhanced through such distributed scaffolding.

Science teachers, too, benefit from scaffolding for their learning. For example, educative curriculum materials – curriculum materials aimed at promoting teacher learning as well as student learning – can scaffold teachers' learning about engaging students in scientific practices by providing both guidance about how to do so and rationales for why it would be important to do so. The scaffolds can be faded over time via a coherent set of year-long curriculum materials. Similarly, approximations of practice in which novice teachers rehearse instructional moves with colleagues or teach a science lesson to a small group of children reflect scaffolded learning experiences in teacher education. Thus, while scaffolding is often investigated in the context of student learning, the construct also applies in the context of teacher learning.

In sum, in designing scaffolding to support students' and teachers' learning in and for science classrooms, designers must consider:

- What meaningful task(s) need scaffolding
- How the individual learner's or collective group's strengths and needs can be diagnosed
- How the support can be calibrated, adapted, and faded for the individual learner and on what basis and on what timeline
- In what ways degrees of freedom can and should be reduced to reduce the learner's cognitive load
- Which most salient features of the task should be emphasized
- What expert guidance should be provided (and how)
- How the task can be modeled for the learner
- How the task can productively be made more complex to promote learning
- What various forms of support should be provided (and how)
- What medium should be used for providing the scaffolding and via what agent
- How distributed scaffolding can be used productively
- How the scaffolding can account for the multiple learners in a setting

Cross-References

▶ Argumentation
▶ Learning Progressions
▶ Socio-Cultural Perspectives on Learning Science

References

Metz K (1995) Reassessment of developmental constraints on children's science instruction. Rev Educ Res 65:93–127

Stone CA (1998) The metaphor of scaffolding: its utility for the field of learning disabilities. J Learn Disabil 31:344–364

Vygotsky LS (1978) Mind in society: the development of higher psychological processes. Harvard University Press, Cambridge, MA

Wood D, Bruner J, Ross G (1976) The role of tutoring in problem solving. J Child Psychol 17:89–100

Scale Scores

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Keywords

NAEP; PISA; Scale scores; TIMSS

Scale scores are derived from responses to assessment items that summarize the overall performance attained by that respondent. The scale scores represent degrees of proficiency in a particular domain. They offer the opportunity to examine the relationships between student performance and various factors measured.

In large-scale surveys such as the Trends in International Mathematics and Science Study (TIMSS), National Assessment of Educational Progress (NAEP), and International Adult Literacy and Life Skills Survey (IALLS), since each respondent responded to just a subset of the assessment items, multiple imputations were used to derive reliable estimates of student performance on the assessment as a whole. Students' proficiencies are generated using as input the students' responses to the items they were given, the item parameters estimated at the calibration stage, and the conditioning variables. The TIMSS eighth-grade reporting metric was established by setting the average of the mean scores of the participated countries to 500 and the standard deviation to 100. For reporting of Programme for International Student Assessment (PISA), results are used scales with an average score of 500 and a standard deviation of 100. NAEP reports the results on a 0–300 scale. The scales arose from the framework being meaningful for feedback and reporting purposes and also defensible with respect to their measurement properties.

Cross-References

- ▶ Assessment: An Overview
- ▶ Assessment: PISA Science
- ▶ National Assessment of Educational Progress (NAEP)
- ▶ Third International Mathematics and Science Study (TIMSS)

School Climate

▶ School Environments

School Environments

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Keywords

School climate

Schools are easily recognized within communities anywhere in the world. They are housed in familiar buildings and share a common purpose – to provide a place for learning (see Hayes et al. 2006). While they have a sameness that identifies them as schools, each is different. These differences can be subtle, but increasingly researchers document cases where the differences are stark. For example, schools in remote rural communities in Australia have difficulty recruiting and retaining qualified physics and chemistry teachers. Unsurprisingly, for this and other reasons, students from these schools perform below the national mean on international tests that measure scientific literacy. Similarly, students from poor urban schools in large cities in North America often do not demonstrate satisfactory science achievement on high stakes tests. Notwithstanding the importance of appropriate funding models that might ameliorate large differences in school environments, this contribution considers how schools can make a difference by improving science learning for students.

Even though the familiar architecture of schools can lead to a sense of sameness about schools, it is what goes on within the buildings and how the extended school community interacts with school personnel that differentiates schools and promotes or hinders students' learning of science (see Cohen et al. 2009). In other words, school climate matters. *School climate* is a collective phenomenon based on patterns of participants' experiences of school life that gives a school its character (Cohen et al. 2009). Four essential and overlapping dimensions of school climate are safety, teaching and learning, relationships, and environmental-structural. The subcategories of the teaching and learning dimension of school climate, most relevant to science education, include the following: quality of instruction; social, emotional, and ethical learning; professional development; and leadership (Cohen et al. 2009). Innovations related to each of these categories are now overviewed.

Quality of Instruction

Students in science classes are frequently portrayed as disengaged because the content lacks relevance to their lives and is delivered through traditional pedagogies that rely heavily on teacher transmission of information. Yet whole-school innovative projects that focus on improving the quality of students' experiences have been documented.

Conceived in 1985 to enhance science students' metacognition, the Project for Enhancing Effective Learning (PEEL) articulates principles of purposeful teaching for quality learning, which emphasize sharing responsibilities for learning with students and generating new pedagogical knowledge while being supportive and collaborative with colleagues. PEEL has sustained decades of success across schools in Australia and more recently in Canada, Denmark, Sweden, and Malaysia.

A more general approach to improving the quality of whole-school teaching, known as *productive pedagogies*, was implemented across numerous schools, particularly in Queensland, Australia (see Hayes et al. 2006). This large-scale innovative project recognized that classroom practice was at the heart of schooling and quality teaching makes a difference to school experiences of students. The productive pedagogies are clustered around four dimensions, namely, *intellectual quality* (higher-order thinking, deep knowledge, deep understanding, knowledge as problematic, substantive conversation, and metalanguage), *connectedness* (knowledge integration, background knowledge, connectedness to the world, and problem-based curriculum), *supportive classroom environment* (engagement, student self-regulation, student direction of activities, social support, explicit criteria), and *working with and valuing difference* (cultural knowledges, inclusivity, narrative, group identities in a learning community, citizenship).

Shared characteristics between successful projects such as PEEL and productive pedagogies should be expected. For example, the first dimension of intellectual quality from productive pedagogies aligns with several of the 12 principles of teaching for quality learning (e.g., share intellectual control with students, encourage students to learn from other students' questions and comments, use a variety of intellectually challenging teaching procedures). As well, several international innovations in science education have focused on specific dimensions and principles. For example, research conducted on context-based approaches to science shows how teachers and students make connections between real-world contexts and concepts. Other innovative approaches to engage students in learning science feature next.

Social, Emotional, and Ethical Learning

A major focus for science education research has been conceptual change from an exclusively cognitive perspective. Yet recent advances in neuroscience have shown that emotions are equally important in learning because almost all brain regions are affected by emotions. So, science teachers who practice quality teaching might be expected to weave affective experiences intricately through classroom activities.

Recent continuing research has shown how students emotionally engage with activities designed around socioscientific issues (e.g., Tomas and Ritchie 2012) that also aim to develop their conceptual understanding of related phenomena and attitudes to science. Socioscientific issues education aims to develop students' moral, ethical, and epistemological orientations through activities in which the moral implications are embedded in scientific contexts (e.g., biosecurity, coal seam gas, organ transplants, and harvesting). A focus on socioscientific issues in the curriculum could help students not only grapple with some of the most complex social challenges of the century but also develop connectedness with their communities (cf. productive pedagogies). Innovative programs in large US urban schools involving socioscientific issues and other curriculum emphases (e.g., C3 curriculum: choice, control, and change) that afford students' opportunities to consider how these issues (e.g., food) impact on themselves have empowered students to connect students' lives to science in relevant and meaningful ways (see Mallya et al. 2012).

Another way teachers and researchers have improved the social and emotional life of students' in science classes is through the dual process of coteaching and cogenerative dialogue (Tobin and Roth 2005). *Coteaching* requires collaboration between teachers who share responsibility for planning and enacting the curriculum. *Cogenerative dialogue* involves different stakeholders from a class meeting from time to time to discuss how learning can be improved in class and to develop action plans that all members take responsibility for enacting. Used together, coteaching and cogenerative dialogue helps teachers to learn how to build collective decisions with colleagues and collaborate with their students to create and sustain effective classroom learning environments. In other words, they provide a context for on-the-job professional development.

Professional Development

If quality teaching through student-centered pedagogies can make a difference to student learning, then structures (or the social arrangements, relations, and practices that exert power and constraint over what individuals and groups can do) that encourage teachers to collaborate for and with their students should be promoted (e.g., coteaching and cogenerative dialogue). Teacher-led professional communities (e.g., those associated with PEEL) also can be effective sites for improving the quality of teaching and learning. Yet it still may be necessary for schools to invest in creating opportunities for teachers to exchange ideas and discuss professional practice as a normal part of the school day (Hayes et al. 2006). This takes leadership.

Leadership

Even though school principals and heads of science departments are important in transforming and supporting climates conducive to the improvement of teaching and learning, all teachers need to lead. The *collective leadership* in schools necessary to improve teaching for student learning involves the shared responsibility of personnel to generate and enact structures that afford agency (or the power to act) to stakeholders (both individuals and groups). The enactment of collective leadership manifests not only as practices such as cogenerative dialogues but also as solidarity among participants and the generation of positive emotional energy through successful interactions (Ritchie 2012).

Cross-References

- ► Classroom Learning Environments
- ► Integrated Curricula
- ► Project for Enhancing Effective Learning (PEEL)
- ► Science Teaching and Learning Project (STaL)
- ► Socioscientific Issues

References

Cohen J, McCabe L, Michelli NM, Pickeral T (2009) School climate: research, policy, practice, and teacher education. Teach Coll Rec 111:180–213

Hayes D, Mills M, Christie P, Lingard B (2006) Teachers and schooling making a difference: productive pedagogies, assessment and performance. Allen & Unwin, Crows Nest

Mallya A, Moore Mensah F, Contento IR, Koch PA, Calabrese Barton A (2012) Extending science beyond the classroom door: learning from students' experiences with the *Choice, Control and Change* (C3) curriculum. J Res Sci Teach 49:244–269

Ritchie SM (2012) Leading the transformation of learning and praxis in science classrooms. In: Fraser BJ, Tobin K, McRobbie CJ (eds) The second international handbook of research in science education. Springer, Dordrecht, pp 839–849

Tobin K, Roth W-M (2005) Implementing coteaching and cogenerative dialoguing in urban science education. Sch Sci Math 105:313–322

Tomas L, Ritchie SM (2012) Positive emotional responses to hybridised writing about a socio-scientific issue. Res Sci Educ 42:25–49

School-Community Projects/Programs

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Introduction

In the past few years, science educators, researchers, and policy makers have been increasingly drawn to the educational potential of school-community projects and programs. “Community-referenced education,” “community-based education,” “community education,” and “place-based education” are all popular contemporary signifiers that serve to distinguish clusters of pedagogical practices that involve schools, classrooms, and students working together with individuals, groups, and organizations mostly located outside of schools. While such programs are driven by a variety of differently nuanced goals, interests, and aspirations, they share a commitment to the considerable educational merits of collaborative practices between diverse communities located in different social, ecological, material, and economic contexts and settings. Through such commitments, these programs nurture pedagogies that are not only about *what* we learn, but also about *why*, *where,* and with *whom* we learn.

School-community programs involve schools working with a large number of different groups including families, youth groups, heritage sites, science institutions, new social movements, government organizations, cultural groups, hobby groups, and businesses. In some cases, these communities are seen, perhaps, more as a “field-resource” with the potential to significantly enrich students’ school-based learning as well as future social mobility. Such projects are conceived and structured to advance the interests of schooling by leveraging the expertise, assets, and resources of community collaborators. Other projects have different, potentially more far-reaching, desires that include school-based reform and community development and building (sometimes alongside school interests). In these cases, school-community collaborations offer opportunities to reflect and act in pursuit of better communities of practices both inside and outside of schools.

Given that school-community projects and programs capture such a wide range of educational initiatives, they defy a straightforward generic checklist of benefits and gains. Programs carry their own distinctive set of evaluative questions concerning how and whether they are working, why and for whom, and under what conditions. Some projects, for example, highlight the benefits of increased and more meaningful, authentic, longer lasting learning. Others explore gains in terms of increased social equality and inclusion, and others focus more on “community building” and/or local ecological restorations and local material enhancements. In the following text we offer brief discussions of selected school-community projects within three broad groups. We then turn attention to some of the tensions that this broad approach to science education presents.

Learning Science Out of School

There are a large number of documented projects in which school students work with a variety of different science-related community groups in out-of-school settings. Within these projects, students encounter science in "everyday" contexts and in so doing, advocates maintain, they develop the ability to learn and use science within "more authentic" settings. including museums, zoos, government organizations, and media. As practitioners and researchers persuasively argue, this type of learning is more meaningful because it is potentially more personalized, contextualized, voluntary, and self-paced. Indeed, much research suggests that exploring science in out-of-school settings can awaken a critical review of the benefits of learning science, as well as how learning might become more empowering. A large number of authors draw attention to the benefits of education projects that challenge youth to collaborate with communities in ways that make their contributions count. Léonie Rennie (2006) describes, to give a couple of environmental examples, educational projects in which youth work with community groups to raise awareness about poor air quality from smoke haze and wood burners and organize a campaign to reduce the indiscriminate killing of venomous tiger snakes. The success of such school-community projects Rennie accredits to a list of generic guiding principles:

- The issue under examination comes from the community and is not imposed.
- Local knowledge is required.
- It is educative.
- Schools are integrated to allow student and teacher participation.
- It involves negotiation and decision-making with the community.
- Outcomes indicate something worthwhile and tangible (Rennie 2006, p. 9).

Science Education as/for Community Development

In a series of influential studies, Wolff-Michael Roth and Angela Calabrese Barton (Barton and Tan 2010; Roth and Barton 2004) investigate students and teachers working with particular local rural environmental groups and urban youth groups on particular community-referenced projects. The studies involve students (and teachers) working with others within specific social, ecological, and economic contexts and settings with pedagogical goals of researching and better understanding shared issues and concerns and shaping common actions. They highlight some of the benefits that this pedagogical orientation provides. These include opportunities to experience the situated nature of knowledge and the interactions of multiple knowledge claims (in which science is one amongst many expert knowledge claims), and the nature and importance of collaboration with ethical responsibilities that active community participation entails (see Roth and Barton 2004). Such projects resist what Paulo Freire calls "banking models of education" and view young people as partners in education as/for social change allied with common social and ecological justice aspirations. This more political orientation provides opportunities to rethink more traditional meanings of "scientific literacy." Over the past decade or so, there is much empirical evidence coming from a variety of different sources that suggests that more locally situated, community-based, politically orientated science education has profoundly positive educational implications for all students, particularly including those who are marginalized by many traditional school-based practices.

Place-Based Science Education

Over the past few years, there has been a steady increase in "place-based" educational projects and theorizing. In much of the recent "place-based" educational literature, there is an emphasis on the prospect of resituating learning within particular communities with critical place theorized aspirations. As David Gruenewald – a high profile advocate of "place-based" education – writes: "human communities, or places, are politicised, social constructions that often marginalize individuals, groups, as well as ecosystems" (2003, p. 7). Approaches to place-based education often entail youth deconstructing the power dynamics inherent to the relationships that people have with places and then collaboratively reconstructing different, more environmentally and socially just relationships. There are a growing number of projects in science education that draw from and extend this approach. “Science in the City” (Alsop and Ibrahim 2008) is one community/place project in which the often “taken for granted-ness” of local places is revisited through activities such as neighborhood walks and photography. This provides a basis to identify issues for further science-based inquiry. Such inquiry has included research with a local medical laboratory to better understand a sister’s illness and offer advice, building gardens to recapture hope from personal loss, and working with local fishmongers to better understand declining aquatic ecosystems and food chains. The project concludes with a celebration of practices and the circulation of a collaboratively written, community-orientated publication.

Some Tensions

Despite many advantages and increased attention in research and policy, there is still a relatively modest uptake of school-community programs in practice. Studies have explored this paradox and brought attention to a number of barriers, including increased safety concerns and administrative requirements, teachers lacking confidence and expertise in this approach, demands of establishing and maintaining community partnerships, and the seemingly ubiquitous and inescapable time pressures of covering traditional curriculum content.

As institutions of science education are being encouraged toward involvement with communities, many (if not most) are also becoming increasingly standardized (through jurisdictional and national curricula) and also more corporatized in nature. The general notion of community-based practices seeks to balance (to a greater or lesser extent) personal responsibility with collective interests and common identity. In contrast, critics of contemporary schooling highlight traditions of individualism, gatekeeping practices, meritocracy, and elitism. What increasingly matters to many schools and governments are economies of performance, examination results, and acceptance rates for further higher-level study. Given these seemingly deep-rooted cultural differences, it is perhaps not surprising that school-community programmatic collaborations can be difficult to establish and sustain.

There are also some theoretical tensions. As the above examples suggest, the concept of “community” has become freely associated with a host of different educational projects, benefits, and desires. The proliferation of the “community” label has resulted in a reduction of meaning and identity. Moreover, the longing for efficacious educational practices at times results in more than a hint of “essentialism” and “valorization.” Communities are complex, multifarious social, ecological, and material manifestations, and while they offer interesting possibilities (particularly in their contrast to school practices), they are neither unitary nor without their own troubles. Some communities will be more educationally desirable; others will certainly be less so. Indeed, in some cases communities will be completely at odds with educational aspirations. The tendency in some educational writing and policy circles to take the concept of community collaboration as “unquestionably desirable” needs our continued reflexive attention.

School-community projects/programs add to an ever-growing list of so-called adjectival educations that demarcate pedagogical, policy, and scholarly turf. Many of these will feature in other parts of this encyclopedia. Subfields can build alliances and allegiances in which practitioners and researchers associate themselves with particular theories and goals; however, these orientations can sometimes take precedence over building broader educational solidarities. Indeed, in this respect, it should be remembered that the concept of community is itself a term of demarcation, which by its very nature is politically both inclusionary and exclusionary. To identify a community is to include and exclude some people on some grounds. Having said this, a shared sense of belonging and a shared sense of identity need not necessarily prevent welcoming others.

There are also associated tensions of "geographical localism." Many school-community programs place an overwhelming emphasis on "the local" and as such raise questions of geographic anchoring and parochialism. Within an era of increased political, economic, and social connectedness, these projects raise questions regarding the local and regional, at a time in which the global and cosmopolitan seems somehow inescapable.

The Future

Clearly school-community programs and projects have an enormous contribution to make to practice and research. While they are not without their own tensions and contradictions, there is considerable empirical evidence in support of far-reaching educational benefits and gains. They offer the prospect of enhancing teaching and learning and also provide a basis for rethinking the nature of science education and schooling itself. Clearly in the future they demand much greater attention in practice and research.

Community-based education has paid less attention to "on-line" communities. Given the popularity of social media, especially with youth, there is a pressing need, perhaps, to better understand and actively explore the possibilities of virtual community-based science education collaborations. This research agenda seems underdeveloped and yet is potentially far-reaching. The growing and impressive literature on school-community projects and programs provides a potential starting point from which to embark on these studies, while recognizing demonstrable differences between "virtual" and "real" educational contexts and settings.

Cross-References

- ▶ Immersive Environments
- ▶ Learning Science in Informal Contexts
- ▶ Science Community Outreach
- ▶ Scientific Literacy

References

Alsop S, Ibrahim S (2008) Visual journeys in critical place based science education. In: Lew Y-J, Tan A-K (eds) Science education at the nexus of theory and practice. Sense Publishers, Rotterdam, pp 291–303

Calabrese Barton A, Tan E (2010) "It changed our lives": activism, science and greening the community. Can J Sci Math Technol Educ 10(3):207–222

Gruenewald D (2003) The best of both worlds: a critical pedagogy of place. Educ Res 32(4):3–12

Rennie LJ (2006) The community's contribution to science learning: making it count. http://research.acer.edu.au/research_conference_2006/8

Roth W-M, Calabrese Barton A (2004) Rethinking scientific literacy. RoutledgeFalmer, London

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Schooling of Science

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Although much research is still needed, the schooling of the sciences (i.e., the way in which science subjects have been incorporated in the school curriculum) has received more attention than most other subjects of the curriculum (DeBoer 1991). Both historical and ethnographic studies (Goodson and Ball 1984) indicate the socially and politically constructed nature of school science curricula and, more particularly, the ways in which both content and pedagogy reflect several widely held assumptions about, for example, pupils' ability, their likely future occupations, the role of women in society, and, ultimately, about the purpose of particular types of curriculum or schooling.

The attention given to school science reflects the fact that aspects of the sciences, such as laboratory work, present unique problems. It is also an acknowledgement that accommodating the scientific disciplines in the curriculum challenged the historical basis of school education. That basis lay in the teaching of the classics and mathematics, subjects whose status as the foundation of a liberal education was legitimized and defended by the universities. In most education systems, the challenge emerged with particular force in the nineteenth century and was directed primarily at those schools such as grammar schools and gymnasia that enjoyed a close historic link with higher education.

The curriculum histories of chemistry, physics, and biology in these schools are different, largely as a result of differences between these subjects and their relative maturity when science was first schooled in the mid-nineteenth century. Despite the scientific revolution of the seventeenth century, physics was professionalized later than chemistry, and in many respects, it can be regarded as a subject constructed from a range of intellectually and socially diverse fields (heat, light and sound, magnetism and electricity, mechanics, and properties of matter) for the purposes of education. In contrast, inorganic and organic chemistry, with a common focus on understanding the preparation, properties, and analysis of materials, offered a more straightforward resource for curriculum construction: physical chemistry was not to gain a place in school curricula until the twentieth century. The timing of the introduction of chemistry into schools also reflected its contemporary salience as a discipline: if the case for teaching science in schools had succeeded in England a generation earlier, it may well have favored geology rather than chemistry. Although biology had long been institutionalized as zoology and botany, the universities offered no “model” upon which a school biology curriculum might be based. In addition, as a school subject, zoology, with its emphasis on anatomy and physiology, was widely judged appropriate only for future medical students, while simultaneously raising concerns about exposing young women to the more intimate aspects of the discipline. The study of systematic and economic botany, along with plant morphology and natural history, represented altogether safer educational territory. However, both botany and zoology were also open to the charge that neither provided an opportunity for experimental work in a teaching laboratory, perceived as an essential condition for accommodation within school curricula. It was not until the mid-twentieth century that satisfactory schemes of work involving observation and experiment and based firmly on general biological principles could be developed. Biology as a discipline therefore secured a place in most school curricula much later than either chemistry or physics.

Unsurprisingly, school science curricula in grammar schools and gymnasia became something of a preprofessional training, supported by a pedagogy similar to that used to teach undergraduates. School chemistry emphasized the preparation, properties, and uses of the elements and their compounds, together with qualitative and quantitative analysis. Physics stressed the importance of precise measurement, an understanding of the basic laws governing, for example, motion, electrical conductivity, and the transfer of heat, light, and sound, along with an ability to solve what quickly became a standardized set of associated calculations. Differences in the science curricula of these schools in different education systems were marginal, rather than fundamental, often reflecting country-specific manufacturing processes or national claims about the priority of scientific discovery.

Where the historic link between schools and universities did not exist, as in the case of the large numbers of schools created to provide public elementary education, the challenge of accommodating the sciences in the curriculum was different and the schooling of the sciences followed a different path (Layton 1973). The scientific disciplines were raided or adapted to construct curricula designed to meet different future social roles and employment needs. Titles such as “How electricity is made and distributed,” “The science of common things,” “The chemistry of everyday life,” “Science in the Home,” “Human Biology,” and “Social Biology” are representative of many initiatives of this kind. In some education systems, broader courses with titles such as “Science” or “General Science” were developed but, despite some success, these ultimately failed to overcome the conceptual, linguistic, methodological, and philosophical differences between the contributing scientific disciplines and they fell out of favor as a demand arose for a greatly increased number of qualified scientific personnel. The challenge for pedagogy, too, was different. Laboratory-based work designed to introduce pupils to the grammar, syntax, and methods of science was replaced by practical activities more directly related to employment, to anticipated social roles, and, in some instances, to wider social and political concerns such as health, diet, and child rearing.

Pedagogy in all types of schools has also been subject to more specific educational influences, notably assumptions about how children learn and should be taught. In many Anglophone countries, the criteria used to determine the order in which topics should be taught was initially determined by the conceptual difficulty that each was presumed to present to students. Thus a course in elementary physical measurements would be followed by the study of heat, light, sound, and mechanics, followed by, or alongside, elementary chemistry. Although this criterion gave way to others, for example, the notion that the interest of children in science exhibited a rhythm corresponding to the rhythm of its history, it was not until the mid-twentieth century that research-based insights into children's learning and understanding of scientific concepts came to play a significant role in determining pedagogy.

In other systems, notably in continental Europe, where educational theorizing was differently conceptualized, the notion of "didactic" was of central importance in the schooling of science. The underpinning notion of didactic is the belief that it is possible to construct a scientific discipline (didactic) by drawing upon a range of other disciplines relevant to the processes of teaching and learning. The difference between these continental and Anglophone traditions remains important, and it is not merely semantic: it reflects contrasting views of what constitutes "scientific research" in education and thus of the role that disciplines such as philosophy, psychology, and sociology can and should play in curriculum construction and pedagogy.

The latter half of the twentieth century was characterized by profound changes in science, in society, and in their interactions and, in some education systems, by major changes in the structure of schooling. A growing postwar demand for qualified scientific personnel, prompted in part by the Cold War, prompted a global movement for school science reform (Rudolph 2002). In the 25 years or so that followed the end of World War II, the scientific content of school curricula was modernized, new assessment techniques developed, and pupils encouraged to learn by engaging in "hands-on" laboratory activities. In some cases, notably at the primary level of schooling, the reform drew upon Piagetian ideas about young people's understanding of fundamental scientific concepts such as mass and time, ideas that eventually led to the development of a substantial field of constructivist research. At the same time, the abolition of selective systems of schooling raised challenging questions about the educational function of school science and highlighted the problem of accommodating the different approaches to science teaching referred to above within a common secondary school.

By the 1970s, a number of other factors had begun to shape the schooling of science. These included the rise of environmental concerns, increased attention to long-standing gender and other equity issues, and the challenge presented by postmodern perspectives on science itself. In addition, there was anxiety, notably in the developed world, about a decline in the popularity of the physical sciences as subjects of advanced study and a recognition of the need for a curriculum response to the growing number of complex ethical and political problems posed by scientific and technological developments. That response took the form of an international science-technology-society (STS) movement (Solomon and Aikenhead 1994). Impelled by a mixture of motives and manifest in diverse curricula, the movement eventually owed less to the community of professional scientists within higher education than to initiatives by science teachers and researchers. Examples include the Science for Public Understanding Program in the USA and the Science and Society Project in the UK. Many of these initiatives made use of the growing power of information and communication technologies, especially the Internet which has become an increasingly important factor influencing how science is taught and learnt.

As the numbers of young people wishing to study science continued to decline in the closing decades of the twentieth century, doubts were raised about the merits of earlier curriculum initiatives as well as the mechanisms used to promote reform. When these doubts were reinforced by the disappointing results of surveys of the level of public understanding of science, attention inevitably focused on the issue of standards of achievement. This later acquired added political and educational salience as a result of international comparative studies such as PISA and TIMSS, the outcomes of which led directly to changes in the school curricula of several countries. The challenge facing all education systems, therefore, was how best to promote the higher and more general scientific literacy deemed necessary for a variety of economic, political, social, and personal reasons. In some systems, government responded to the challenge by taking direct control of the science curriculum and its assessment, specifying intended and measurable learning outcomes and offering suggestions for best pedagogical practice. Where central government control of schooling was not possible, as in the USA, it was necessary to respond in ways that accommodated the delocalized nature of curriculum control.

As governments have demanded greater accountability of investment in schooling, they have inevitably gained greater influence over what and how school science is taught and assessed. This has created an educational bureaucracy that, in many countries, has overturned the historic roles accorded to academia and science teachers to determine the form, content, and pedagogy of school science. The longer-term consequences of this shift in authority remain to be determined.

Cross-References

- ▶ Bildung
- ▶ Competence in Science
- ▶ Curriculum Movements in Science Education
- ▶ Didaktik
- ▶ Primary/Elementary School Science Curriculum Projects
- ▶ Relevance

References

DeBoer G (1991) A history of ideas in science education. Teachers College Press, New York
Goodson IF, Ball SJ (eds) (1984) Defining the curriculum: histories and ethnographies. Falmer Press, London
Layton D (1973) Science for the people: the origins of the school science curriculum in England. Allen and Unwin, London
Rudolph JL (2002) Scientists in the classroom: the cold war reconstruction of American science education. Palgrave, New York
Solomon J, Aikenhead G (eds) (1994) STS education: international perspectives on reform. Teachers College Press, New York

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Science and Mathematics Teacher Education

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Keywords

Mathematics; Pedagogical knowledge

This entry will consider how and why science and mathematics have been linked in teacher preparation programs in ways that influence notions of content knowledge and pedagogy.

How Similar Is Teaching in Mathematics Compared to Science?

While the obvious importance of mathematics to scientific endeavor might seem to indicate an obvious link between science and mathematics teaching and learning, the structure and guiding principles for school curricula in the two areas are substantially different (Siskin 1994).

Mathematics tends to have a highly sequential curriculum structure, whereas science curricula are organized around topics that are not tightly sequenced. The pedagogies in the two areas tend to differ, with mathematics teaching emphasizing sequenced practice in problem solving and science teaching incorporating substantial experimental work and practical application of concepts.

Studies of science and mathematics specialist teachers teaching across this disciplinary boundary have indicated a significant “boundary crossing” issue with teachers committed to distinctive aesthetic features of their preferred subject and to different narratives around which the subjects are made meaningful for students (Darby 2008; Darby-Hobbs 2013).

Policy and Practicalities Linking Science and Mathematics

Nevertheless, there are practical reasons why the two subjects are linked in the public mind and in teacher preparation programs. First, both subjects are grouped under the general STEM (science, technology, engineering, and mathematics) banner describing the areas that form the backbone of a nation’s technological enterprises. As such, the problems of attracting and engaging students into science and mathematics subjects are related. Student attraction and retention in mathematics and physical science/engineering subjects have similar historical profiles. Similarly, there has been a similar trajectory of problems in attracting and retaining teachers of mathematics and of science. A search on science and mathematics education immediately identifies numerous government policy initiatives in many countries that treat the areas as strongly linked through their contribution to STEM professions. Policy initiatives focused on student and teacher attraction and retention into the STEM area lend credence the idea of linking the areas in teacher training.

Because of the substantial mathematics component of most science degrees, preservice teachers (PSTs) will often be qualified to teach in both areas, and combining them in a teacher preparation program offers efficiencies. In postgraduate entry programs also, mature age students with engineering or technology backgrounds will often have expertise and qualifications in and commitment to both areas. The opposite face of this coin is that elementary teacher trainees have been reported to experience similar issues with confidence and self-efficacy in the two subjects.

The reality in schools (in some countries at least – including Australia) is that in the face of a shortage of qualified mathematics or science teachers, teachers qualified in these subjects are the most likely to be called upon to teach across the science-mathematics subject boundary – to teach “out of field” (Ingersoll 2003; Hobbs 2012). Given the argument above, that the two subjects differ considerably in the structures and pedagogies of their traditional school forms, this would indicate another reason why PSTs in the two subjects should be exposed to the pedagogical traditions across the boundary and be provided with strategies for making the crossing.

In any teacher education program, there exists a tension between the need to introduce teachers to the pedagogical traditions and substantive knowledge of their specialist field and the need to develop their general pedagogical orientation and their identities as teachers per se. With regard to teaching and learning, this issue is informed by Shulman’s (1987) description of teacher knowledges which include content knowledge (CK), general pedagogical knowledge (PK), and pedagogical content knowledge (PCK) which refers to knowledge of curriculum organization and structural traditions, of student learning challenges, and of teaching approaches specific to the subject. There are choices to be made as to where to put the emphasis in a teacher education program – whether to focus on maximizing knowledge of the chosen disciplinary area (e.g., science, or mathematics, separately) or whether to develop structures that allow more emphasis on general pedagogical knowledge with less time devoted to discipline specifics.

Given the likelihood that teachers in their career may be called upon to teach across a number of subjects, there is an argument that a prime aim of a teacher education program should be to produce teachers who are adaptable, able to take up challenges of teaching across fields such as science and mathematics. This is one aspect of the argument for bracketing science and mathematics teacher education.

Another argument was particularly strong in writing in the 1990s, advocating the integration of science and mathematics at the school subject level (Pang and Good 2000). This was a specific instance of arguments for curriculum integration more generally, pointing to the flexibility of integrated curricula and the enhanced possibility of building student knowledge around authentic, contextualized problems that drew on a range of disciplinary traditions.

Research in Science and Mathematics Education

Research often links science and mathematics teaching and learning. A number of journals cover both areas (Research in Science and Mathematics Education, School Science and Mathematics, Canadian Journal of Science, Mathematics and Technology Education). In the research literature, theoretical advances and perspectives have followed similar trajectories in science and mathematics education more so than for other disciplines. Constructivism for instance was a big issue in the 1990s in both subjects (Wheatley 1991), although the pathways it took and the presumptions made were different. Conceptual change approaches have been important in science education but have been pursued in mathematics also (Vosniadou 2008). Similarly, current concerns with social constructivist and sociocultural perspectives and the role of representations are current concerns driving much new thinking in both subjects. The work of Richard Lehrer and Leona Schauble, for instance, explores model-based reasoning and classroom representation construction in the context of both science and mathematics (Lehrer and Schauble 2004, 2005).

Educators calling for reform in the two areas have similar agendas; the emphasis in science is on inquiry approaches and the inclusion of socioscientific contexts into the curriculum to make science more meaningful. These reform agendas (Tytler 2007) critique the traditional transmissive pedagogies common in school science. In mathematics, there have similarly been strong movements towards problem solving and “real maths” with a contextual underpinning. The critique here has been the instrumental focus of traditional mathematics teaching. Calls for reform in both subjects emphasize higher-order thinking and scientific literacy/numeracy, as a major aim. Thus, insofar as teacher education programs draw on current research, productive links can be made between the research literatures in mathematics and science.

Cross-References

- ▶ Secondary Science Teacher Education
- ▶ Science, Technology, Engineering, and Maths (STEM)
- ▶ Third International Mathematics and Science Study (TIMSS)

References

Darby, L (2008) Negotiating mathematics and science school subject boundaries: The role of aesthetic understanding. In Thomase MV (ed) Sci in Focus. Hauppauge, NY: Nova Science Publishers, pp. 225–251

Darby-Hobbs L (2013) Responding to a relevance imperative in school science and mathematics : humanising the curriculum through story. Res Sci Educ. doi:10.1007/s11165-011-9244-3 43(1):77–97

Hobbs L (2012) Teaching out-of-field: factors shaping identities of secondary science and mathematics. Teach Sci 58(1):32–40

Ingersoll R (2003) Out-of-field teaching and the limits of teacher policy. University of Pennsylvania Scholarly Commons. http://repository.upenn.edu/gse_pubs/143. Accessed July 2012

Lehrer R, Schauble L (2004) Modeling natural variation through distribution. Am Educ Res J 41(3):635–679

Lehrer R, Schauble L (2005) Developing modeling and argument in elementary grades. In: Romberg TA, Carpenter TP, Dremock F (eds) Understanding mathematics and science matters. Lawrence Erlbaum Associates, Mahwah, pp 29–53

Pang J, Good R (2000) A review of the integration of science and mathematics: implications for further research. Sch Sci Math 100(2):73–82

Shulman LS (1987) Knowledge and teaching: foundations of the new reform. Harv Educ Rev 57(1):1–22
Siskin LS (1994) Realms of knowledge: academic departments in secondary schools. Falmer Press, Washington, DC
Tytler R (2007) Re-imagining science education: engaging students in science for Australia's future. Australian Education Review No. 51. Australian Council for Education Research, ACER press, Camberwell. www.acer.edu.au/research_reports/AER.html
Vosniadou S (2008) Handbook of research on conceptual change. Routledge, New York
Wheatley G (1991) Constructivist perspectives on science and mathematics learning. Sci Educ 75(1):9–21

Science and Society in Teacher Education

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Keywords

Science education; Society

Background

Contemporary science education serves the dual role of training future scientists and educating future users of scientific knowledge. This presents science teachers with the challenge of developing both students' understanding of scientific knowledge and their awareness of the interactions between science and society to deliver the benefits of science while avoiding the pitfalls. The connection between science and society has become increasingly complex in light of the rapid advancements, in science and related technologies that permeate our lives, intertwining with consumerism, economic developments, and politics. This saturation is evident in the many science-related claims advertised by consumer products and the large-scale national development plans advanced by politicians to boost the economy that may ultimately endanger our natural environment.

The Aim of Science and Society Education

These developments have required that science students engage in increasingly complex inquiries from multiple outlooks when addressing science and society, including technological, epistemological, politico-economic, sociocultural, and moral/ethical perspectives. Such inquiries have evolved into different forms, as reflected by the jargon involved in the curricular movements that have sprung up in recent decades, such as *Science for All*, *Science-Technology-Society (STS)*, *Scientific Literary*, *Socio-scientific Issues (SSI)*, and, the latest, *Science Proficiency* (National Research Council 2007). The emphases of these curriculum movements with respect to science and society appear to have shifted from learning scientific concepts using related technologies and understanding such technological applications and their social and ethical implications to developing critical thoughts about scientific practices within society and their place within sociocultural contexts. The most recent of these emphases have included evaluating scientific evidence in authentic contexts, weighing the pros and cons of decision alternatives from both scientific and nonscientific perspectives, and formulating criteria underpinned by moral or value judgments to imbue students with a more thorough understanding of the role and limitations of science in society that cultivates informed decision-making congruent with this understanding. Thus, science and society education aims to develop not only scientifically knowledgeable citizens, but also critical thinkers who are aware of the scientific practices applied in society and capable of engaging in discourse at the science-society interface.

Implications for Teacher Education

To achieve this aim, teachers must develop a knowledge base comprising three interrelated components: content knowledge of the relationships between science and society; thinking processes involving argumentation, reasoning, and decision-making about socio-scientific issues; and the pedagogical knowledge and skills needed to lead students to achieve the aforementioned aims. Each of these knowledge components begs a multitude of questions that serve as a foundation for science teachers preparing to address matters of science and society. The content knowledge explores what roles science has played in the shaping of societal development and how the work of the scientific community has been influenced by the social, cultural, and political milieus. It also analyzes how the nature of science enhances and limits its role in society. Regarding thought processes, as students must learn how to determine the trustworthiness of science-related claims by evaluating scientific evidence and how to negotiate disagreements over conflicting science-related claims, teachers must discover what types of argumentation, reasoning, and decision-making frameworks are available to guide these processes. As for pedagogy, teachers must show students how to evaluate claims and evidence in authentic contexts that are much messier than the seemingly uncontested textbook knowledge and controlled experiments they have become accustomed to in laboratory environments. It raises the question: How can teachers possibly assume leading roles in an emergent area of science education in which they can claim no expertise?

Implications for Learning

Meeting these challenges requires that science teacher education be rethought, with new pedagogies grounded in research to enable teachers to take full advantage of the potential learning opportunities that science and society education offer. The learning experiences provided by these pedagogies should exhibit four essential characteristics. First, they should be contextualized and situated preferably in current socio-scientific issues to increase relevance and motivation. This would address the problem of learning canonical science in a decontextualized manner, as is commonly practiced in science classes.

Second, learning should be integrative so that the science and society components are not seen as merely an "expensive elaboration" of the curriculum in terms of time or as an "armchair discussion" that bears little relationship to a declarative or procedural understanding of science. Science and society education must be successfully integrated with conventional science educational goals to achieve a holistic science curriculum that produces and promotes scientific literacy. Such integration could be achieved by situating the learning of relevant scientific concepts and processes, along with the nature of science, in the context of socio-scientific issues. Because the scientific concepts involved might not be readily linked to textbook knowledge, self-directed learning strategies such as problem-based learning (PBL) might need to be employed to encourage students to apply previous knowledge and problem-solving skills to the construction of new knowledge that is essential to the issue being studied.

Third, learning should be interdisciplinary because the compartmentalization of knowledge is by no means conducive to learning in authentic socio-scientific contexts, which entails multi-perspective thinking. As a prerequisite, science teachers should give up a certain degree of territoriality to draw on knowledge and skills from disciplines such as citizenship and value education.

Fourth, the learning process should be collaborative and interactive because recent research has shown that the reasoning and decision-making involved in addressing SSIs are mediated by contextual variables (Lee and Grace in press). Given this, teachers must facilitate the social construction of knowledge and collaborative decision-making through group discussion and, if possible, cross-contextual or cross-cultural sharing that brings students' backgrounds to bear in argumentation and decision-making. This collaborative knowledge construction process is congruent with how science knowledge is generated within the scientific community, how public policies are created in democratic societies, and how global issues are negotiated by international communities.

Conclusion

Considering the diversified and complex nature of the inquiries required by science and society education, the teaching of science and society defies any uniform teaching protocol or approach. Teachers must be flexible in organizing learning experiences that fit into their school science curricula and the wider societal context in which relevant socio-scientific issues arise.

Cross-References

- ▶ Environmental Teacher Education
- ▶ Pedagogy of Teacher Education
- ▶ Science, Technology and Society (STS)

References

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

Lee YC, Grace M (2012) Students' reasoning and decision making about a socio-scientific issue: a cross-context comparison. Sci Educ 96(5):787–807

Lee O, Luykx A (2007) Science education and student diversity: race/ethnicity, language, culture, and socioeconomic status. In: Abell SK, Lederman NG (eds) Handbook of research on science education. Lawrence Erlbaum, Mahwah, pp 171–197

Martin MO, Mullis IVS, Foy P, Stanco GM (2012) TIMSS 2011 international results in science. TIMSS & PIRLS International Study Center, Boston College, Chestnut Hill

Sjøberg S, Schreiner C (2010) The ROSE project: an overview and findings. http://roseproject.no/network/countries/norway/eng/nor-Sjoberg-Schreiner-overview-2010.pdf. Retrieved 19 Jun 2013

Science and Technology

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Keywords

Technology; Values

Introduction

Over the last three decades, there have been significant changes in teacher education and the place of science within this. For example, there has been varying emphasis on general science, integrated science, and STEM. This entry focuses on possible interactions between science and technology in teacher education.

Technology, here, encompasses more than just ICT. Rather, it is seen to be a dominant part of our culture and the world we inhabit. People develop and use technologies to intervene in this world to expand human and environmental possibilities. Technological endeavors encompass a broad range of activities including the transformation of energy, materials, and information in products, systems, and environments (Jones et al. 2010). Many school curricula package these as electronics and control technology, food and process technology, and materials technology and production. Within science education, technological examples are often presented to demonstrate scientific concepts. Context-based approaches to science education also often use technological examples to engage students in learning. Curriculum innovations such as science, technology, and society (STS) and Science, Technology, Engineering and Mathematics (STEM) expand on this to integrate technology in science. However, within these approaches, technology is often characterized and taught as applied science.

Science Teacher Education

In thinking about the role and place of technology in science teacher education, it is important to consider the characteristics and nature of technology (refer to entry on Technology Education and Science Education for a discussion of similarities and differences between science education and technology education, as well as the nature of technology). However, the distinction between science and technology is not often considered to be important in the teaching and learning of science. Neither is it at the forefront of science teacher education at both the pre- and in-service levels. This is likely because of the perceived similarities between the two fields, conflated with the perennial challenge of deciding which content to prioritize when only a limited amount of time is allotted to science and/or technology as part of a teacher education program.

The risk of not exploring the differences between science and technology can mean that preservice teachers and their eventual students develop limited understandings of the nature of each field. For example, science is often seen as the precursor to technology (technology as applied science). This can be reinforced by the frequent use of technological applications to exemplify a scientific concept. However, it does not lead to understanding of other possible relationships between science and technology. Similarly it does not provide students with opportunities to consider how technology shapes their world and how they might contribute and/or respond to this. As argued elsewhere, understanding the relationship between science and technology and society is about not only learning the "rules of the game" but being in a position to critique these rules and feel empowered to change them (Buntting and Jones 2009).

It is also important to consider both the nature of science and the nature of technology as part of teacher education so that early childhood and primary teachers, who often integrate curriculum areas in their classroom programs, can develop robust understandings of both in order that their teaching maintains the integrity of each discipline as an area of inquiry and development with its own sets of values and processes (Jones 2007). At the secondary level, newer technologies such as biotechnology often require that science specialists contribute to technology programs. Again, a robust understanding of the differences between the nature of science and the nature of technology is necessary so that students can be taught to understand what questions science (or technology) can and cannot answer.

International trends around the introduction of STS and Socio-Scientific Issues (SSI) require teachers who are confident in knowing what the science is, what the technology is, and their impact on society and social issues. Integrated approaches to STEM similarly require teachers to have an understanding of each of these disciplines and the interactions between them. These developments can engage school students and contribute to developing their understandings in and about science. However, they add complexity to science teaching and learning and teacher education in science.

An essential part of teacher education in preparing generalist primary teachers and specialist secondary teachers is to expand preservice teachers' understanding of the nature of science and the nature of technology. In doing so, it is important that the similarities and differences between science and technology are explored. Focusing on the nature of science (and comparing it with the nature of technology) has the potential to expand both preservice and in-service teachers' concepts of science as well as enhance their confidence to engage with their students and also with a variety of science resources.

Conclusion

Given the traditional separation of science and technology as distinct school disciplines, supporting both preservice and in-service teachers to consider the nature of both science and technology will require deliberate intervention. Finding teacher educators who themselves have a robust understanding of the similarities and differences between science and technology – and what this means for science education – remains a significant challenge.

Cross-References

- ▶ Science, Technology and Society (STS)
- ▶ Science, Technology, Engineering, and Maths (STEM)
- ▶ Socioscientific Issues
- ▶ Technology Education and Science Education

References

Buntting C, Jones A (2009) Unpacking the interface between science, technology, and the environment: biotechnology as an example. In: Jones A, de Vries M (eds) International handbook of research and development in technology education. Sense, Rotterdam, pp 275–285

Jones A (2007) The valuing of technology in the science curriculum. In: Corrigan D, Dillon J, Gunstone R (eds) The re-emergence of values in science education. Sense, Rotterdam, pp 89–100

Jones A, Cowie B, Moreland J (2010) Assessment in schools – technology education and ICT. In: Peterson P, Baker E, McGaw B (eds) International encyclopedia of education, vol 3. Elsevier, Oxford, pp 311–315

Science Beyond the Classroom

► Out-of-School Science

Science Books

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Books have a long-standing high profile position in science education. It is hard to pin down precisely whether they have any significant educational impact. What is discernible is that they have impact ascribed to them, with scientists frequently referring to the inspirational power of the popular science books (and science fiction) they read as children. Books for adults are also often cited in terms of the public understanding of science and/or political support for science funding.

Overviews of the histories and ideologies of popular science aimed at adults are available elsewhere, so this entry will focus on some of the history and diversity of science books for young people. Most of the examples sit within the 7–11 years age range, largely because this is the age that children's popular science books are produced for. What might be defined as a children's science book will always be reasonably open as we might unpack any of the terms *children's*, *science*, or *book*. Indeed, the books themselves may help articulate the boundaries around such ideas.

Instructive and Amusing

For all that "edu-tainment" is seen as a new term, Arabella Buckley's 1879 *Fairy-Land of Science* is a classic example of the genre. Aiming to cash in on the Victorian mania for fairies, she cloaked the science in the language of fairy stories; her fairies were the forces of magnetism or gravity, with a message that the wonders of science were not only parallel to but could surpass the wonders of fairyland. A more explicitly masculine attempt to similarly apply narrative can be seen in *Peter Parley's Wonders of the Earth, Sea and Sky,* a "thrilling" nature of geology, geography, and meteorology popular in middle-class homes from its publication in 1837. The use of such fantasy and/or travel narratives is still applied today, taking nonfiction readers to semi-fantastical worlds constructed from scientific ideas. Such books might shrink a character so they are small enough to play with atoms or travel fast enough to explore relativity. (Joanna Cole's *Magic School Bus* series and Russell Stannard's *Uncle Albert* books are two popular recent examples.)

A common trait of nineteenth-century children's publishing that is less readily tracked today is an overt connection between studying nature and learning about God. Books would often invoke a sense of wonder by presenting science as a way to learn more about God's creation. In the contemporary scene, the glossier end of children's nonfiction – e.g., *Eyewitness* books – provides a good example of a similar, albeit less religious, appeal to wonder. Full of lavish color photography, the typography of such books is perhaps comparable to glossy magazines such as *Vogue* or *National Geographic*. In contrast, cheaper books such as *Horrible Science* and *Grossology*, which owe more to the aesthetics of *Beano* or *Nickelodeon*, are more likely to appeal to a perceived sense that young people enjoy scatological humor. This does not mean they lack an appeal to wonder; it is just a different style of fascinating they are appealing to, with perhaps less mainstream appeal. Indeed, the idea that only the childish would find this interesting (and that it is slightly taboo in adult life) is perhaps part of the appeal, as young people's media increasingly defines itself via an othering of or from adult life. Although books applying a less glossy aesthetic may also laugh at the pomposity of adult science life, they can also be very reverent towards scientific expertise (see Bell 2008).

Shopping for Science

Books sit in an interesting position economically and socially compared to much other public-orientated science communication. There is an upfront cost, compared to free at the point of click sites such as Wikipedia, or a museum or television show which might be funded by public, charitable, or advertising bodies. Reading a book also implies some time, although without much commitment. Whereas a degree course in a science subject takes significant time and money; a book – especially since the advent of paperbacks – is relatively cheap and portable, easy to keep in a pocket, and dip into around the rest of the day. This, in turn, arguably has an impact on the relationships they may assume with readers and the relationships between science and a public they may help produce.

To Fyfe and Lightman (2007), the idea that the popular science consumer may shop for science puts them in a relative position of power with respect to science. Rather than simply being talked down to – as one might imagine the traditional model for the public understanding of science – the consumption of popular science in a marketplace allows people some degree of choice. Such analysis, however, is based on a rather uncritical view of consumer power. For child consumers of science in particular, it is worth noting that although there are increasing numbers of science books pitched at the pocket money market (compared to glossier books designed to be given as gifts or school prizes), it is possible to argue that children's media are never really owned by the child, rather it is a matter of what adult authors, librarians, parents, and teachers think the child would (or should) enjoy (c.f. Buckingham 1995). It is also worth noting that when it comes to children's science publishing, many books are connected to formal learning, even carrying logos of government education. Such science books are often associated with the "topping up" of the education of middle-class children and, for a host of economic, social, and cultural reasons, are more likely to be used by a privileged few. Their role in supporting formal education might also mean they act as an encroachment of school life on more domestic "play" time.

Interaction

It is notable that the book is a rather individualistic way to consume science, compared to the more group-based experiences of schooling, television, or museum visits. Still, it is worth remembering that books always sit in a social network. For example, children's reference books stay around for decades after they might otherwise do, due to use as school prizes. Also, recent years have seen a rise in popular science book clubs (including those for children who used to judge the Royal Society's children's book prize) as well as authors turning to online social media in ways that not only promote their works and interact with readers but allow readers to interact with one another.

The chief form of interaction offered by children's science books is with the physical, not social, world. In some contrast to the literary/fantastical experiences referred to earlier, many science books promote a very hands-on way of learning science. Indeed, children's science books in particular are striking in their attempts to transcend the traditions of a book form. The more complex examples include stickers to move around (e.g., of partly digested food around a diagram of the gut or magnets hanging from the spine or embedded in pages), and the field of nonfiction pop-up books is flourishing. More simply, there is also a long tradition of books with instructions on how to perform "experiments" – actually demonstrations of known phenomena, they are not experimental – of which John Henry Pepper's *Boy's Playbook of Science*, first published in 1860, is an iconic example (see Secord 2002, for an excellent description to this). Books which play on the empirical associations of scientific work did not end with the *Playbook*. This is perhaps most noticeable in the US market, where instruction manuals for science fair activities dominate the children's science shelves. Still, arguably this is more activity than interactivity. If anything, it is largely a rather conservative form, sometimes dressing up fixed, stabilized, and reasonably old science as if it was fresh and young, but rarely offering anything new, or the opportunity for young people to creatively make something entirely new themselves.

Children's science books are a reasonably diverse field. There are trends as sketched here – of interactivity, reverence to scientific authority, and careful application of fiction for expeditionary purposes – but no tight hallmarks or standout literature in the field. It is common to end such pieces with a general open-ended statement about how the field is always changing and who knows what will happen next. However, despite being aimed at young people and about the supposedly ever changing field of scientific research, another characteristic of children's science books is that they tend to be rather conservative, often rooted in the science (and images of childhood) of at least a generation before the intended audience. It would be nice to think future authors and editors will find it in themselves to be a bit more innovative, but whether or not this happens remains to be seen.

Cross-References

- ▶ Print Media
- ▶ Science Fiction

References

Bell A (2008) Science as pantomime: explorations in children's contemporary non-fiction books. PhD thesis, University of London. Copy available on email request

Buckingham D (1995) On the impossibility of children's television: the case of Timmy Mallet. In: Bazalgette C, Buckingham D (eds) In front of the children: screen entertainment and young audiences. BFI Publishing, London, pp 47–61

Fyfe A, Lightman B (eds) (2007) Science in the marketplace: nineteenth-century sites and experiences. University of Chicago Press, Chicago/London

Secord JA (2002) Portraits of science: quick and magical shaper of science. Science 297(5587):1648–1649

Science Centers

▶ Interpretive Centers

Science Circus

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The circus proper has a great antiquity. The word derives from the ancient Greek *krikos*, which became, by an inversion, *kirkos* and thence the Roman *circus*. A circus is traditionally defined by its central ring in which performances take place. However, in recent years, it has come to mean almost any spectacular display, such as the American "barnstorming" flying circuses of the 1920s.

Travelling shows are as old as civilization. The first travelling performers probably appeared at the same time as the first villages and towns. Ancient Rome enjoyed its histrions, usually freed slaves who went about entertaining crowds with storytelling, music, songs, juggling, and acrobatics – what, today, we would call busking. In the Middle Ages, minstrels and jongleurs travelled between European towns fulfilling the same role. Miracle plays, in which religious scenes were enacted for delighted crowds, were also a feature of the Middle Ages. First an initiative of the people, they were later taken over by the guilds, each of which had developed its own play. Later, the plays were staged on movable carts and taken around so that more people could experience the wonder and the message. All of these forms were able to present secular, political, and religious information wrapped up as entertainment.

In the eighteenth and nineteenth centuries, and particularly in the southern states of America, travelling medicine shows flourished. While not exactly about science, more about snake oil miracle cures, there was a clear perception that placing a product in the enjoyable context of entertainment created a positive attitude toward the product, resulting in increased sales.

Among the first genuine travelling science shows – in this case the applied science of agriculture – was the Canadian *Better Farming Train*. Agricultural fairs, in which exhibits were assembled in one place to which farmers travelled, were a feature of the Canadian scene from 1894. As the distances involved were a disincentive to travel, in 1914 *Better Farming Trains* began to carry agricultural innovation by rail to farmers in rural Saskatchewan. Hundreds of thousands of people were educated and entertained between 1914 and 1922, when the program was discontinued.

Two years later, in 1924, Australia got its own *Better Farming Train*. It was based in Victoria, and like its Canadian counterpart, it carried pigs, cows, poultry, bees, dairy utensils, potatoes, bacon, tobacco, manure, fodder and pasture samples, and a range of expert lecturers. Between 1924 and 1935 it made 40 trips to ten regional centers. Lectures and demonstrations of infant welfare, cooking, and sewing were offered. The train served as an agricultural school, an experimental farm on wheels, and a chance for a day out for all the family.

While none of the above is a circus in the accepted sense of the word, they share the concept that the delivery of a message accompanied by entertainment is more effective than a message delivered on its own. The success of the *Better Farming Trains* was due, in part, to the fact that Canada and Australia were, at that time, large and relatively undeveloped countries with sparse up-country populations who found it difficult to journey to the cities.

One of the traditional values of the orthodox travelling circus is teamwork. Everyone lends a hand at the various tasks necessary to get a show ready. Erecting the tent, the “Big Top,” is a task that requires everyone’s muscles. The high-flying trapeze artist may be found later selling popcorn and ice cream to the public. The clowns may lend a hand cleaning up after the elephant.

In Australia, in 1986, a large van left Canberra to journey to Goulburn, about 80 km distant. It carried Dr. Mike Gore, some demountable science exhibits, four keen science students, and the germ of an idea. The idea was for a travelling science circus that would cross the length and breadth of Australia, bringing science to remote rural communities. It was a spin-off of Questacon – the Australian National Science Centre that started its embryonic life in the backroom of the physics department of the Australian National University (ANU), grew up in a disused primary school, and came to maturity as a major national institution. Gore was the first director, and the word *National* in the title caused him to grapple with the problem of reaching out to all Australians, not just the local region. With support from Shell Australia, support that continues to the present day, the Shell Questacon ANU Science Circus was born.

For 2 years the Questacon Science Circus was served by selected students from ANU who had been trained as explainers. With Questacon’s transformation into the national center, the decision was made to select a more nationally representative circus team. In 1987, therefore, the ANU and the center established a 1-year graduate certificate in science communication, the first of its kind in Australia and, probably, the world. Competition for places was strong as scholarships were (and still are) awarded to successful applicants. In 1991, the certificate was upgraded to a graduate diploma and in 2012 to a masters degree.

The circus is an institution in which the scholars undertake coursework at the ANU and develop a wide range of skills when on the road. These skills range from learning to present science shows live at schools and other venues, mastering the techniques of educational radio on school of the air, loading, safely, a giant articulated truck with exhibits, acting as floor managers when the circus sets up in show grounds, and becoming exhibit repairers to staffing the circus shop. No task is too menial, and while there are no elephants to clean up after, there are often over excited children!

The primary function of the circus is thus to take science and present it to the people of

Australia, especially the indigenous people, to show that it is both relevant to their lives and a stimulating and enjoyable enterprise. A secondary object is to let a number of gifted and confident young scientists advance their own development with the support of ANU and Questacon. The skills they acquire with the circus and its rapidly growing reputation are such as to make them much sought after in Australia and overseas.

There are very few science circuses. The Canadian *Super Scientific Circus* has been operating since 1994. In its own words, it makes *science fun and funny, using amazing and amusing magic tricks to create visual images for scientific concepts*. While it does not go on the road, it can be booked into theaters, performing arts centers, state fairs, schools, libraries, museums, and science centers. The author understands that it supercedes an earlier model in Ontario that was discontinued.

The success of the science circus in Australia is remarkable and it has won several prestigious awards. In particular, the association between the National Science Centre, the National University, and Shell, extending now over 26 years, has been highly commended. It is, however, worthwhile mentioning two aspects that, more than anything else in the opinion of the author, have led to this success. The first is the scholars themselves. The first team comprised only 8; in 2012 there are 16. They are uniformly young, intelligent, enthusiastic, and energetic. They stay with the circus for 1 year only and then are replaced by a new crop. Enthusiasm and innovation are thus renewed annually; each year a brand new team is sent out to schools and communities to carry the message of science.

The second reason is the accident of geography. Australia is huge (7.7 million square kilometers) with only 22 million people, 12.5 million of whom live in the five largest cities. The remaining ten million are spread across the country and make rare trips to the big metropolises. These are the clients of the circus, which travels thousands of kilometers each year. In England and much of Europe, a major city is rarely more than a short rail trip away. A science circus along Questacon lines would scarcely be viable although more local and smaller travelling shows have been successful. There are, however, other similarly large countries that might benefit, as experience in Canada has shown. Recent trials in South Africa have shown that a travelling science circus can be successful there, and a Cape to Sahara Science Circus is being considered.

Cross-References

- ▶ Learning Science in Informal Contexts
- ▶ Science Community Outreach

Science Communication

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Science communication has been described as a process by which the scientific culture and its knowledge become incorporated into the common culture. This broad definition encompasses a variety of communication styles which may be envisaged as being distributed across a continuum. On this continuum, simple one-way communication of science is at one end, with many who term themselves *science communicators* engaged in one-way activity. *Science journalism* is in this category; it also includes informative articles in the press, screening a television documentary, placing science on the Internet, or presenting a new exhibition in a science center. There is clearly no expectation by the writers, designers, and producers that they will engage in two-way communication, but rather that they are *transmitting* information to whatever audience is willing to listen, play, read, or watch. One-way communication of science also promotes science careers and the need to improve the poor science performance of many school students. Many aspects of science education, with its prescribed learning outcomes, fall into this part of the continuum. It is not, however, the only or perhaps the ideal way to communicate science.

In the 1980s, the movement known as the *Public Understanding of Science* (PUS) became concerned for public scientific literacy. Efforts were made to improve public education in science, assuming a deficit in public knowledge which required to be filled. The assumption was that increased knowledge of science would result in increased acceptance of science. The PUS movement prompted the rise of science centers, festivals, and so on, all aimed at informing an uninformed public. The development of science performance skills in these informal learning arenas has given rise to a narrower definition of science communication as "the use of appropriate skills, media, activities, and dialogue to produce one or more of the following personal responses to science (the AEIOU vowel analogy): Awareness, Enjoyment, Interest, Opinion-forming, and Understanding" (Burns et al. 2003, p. 191).

The PUS movement of the 1980s also gave rise to science communication as an academic discipline. In the 1990s, a number of tertiary programs in science communication was developed under the umbrella of science faculties. This was a marked change from courses in science journalism taught by communication departments. Since the 1990s, science communication as a discipline has constantly been modified in the light of new perceptions of what it means to communicate science. What is now considered to be the ideal mode of communication has shifted from one-way transmission to some form of two-way, participatory practice. This therefore represents the other end of the continuum – a process of knowledge sharing and knowledge building that incorporates dialogue and consensus, decision-making, and policy formulation. The contribution of indigenous science is part of this knowledge-sharing approach.

Definitions of science communication which deal with diffusion of expert knowledge, or the media as the information source, do not incorporate this broader vision of what it means to communicate science. It is now widely recognized that knowledge *deficits* are not restricted to the general public or to *nonscientists*: they apply to all participatory groups, including *experts* (Stocklmayer and Bryant 2012).

The term *public engagement* has been coined to replace PUS. It acknowledges that the communication of science with a broad public is important, especially when concerned with issues of democracy. It is notable that notions of the nature of science are not the same in the public domain as they may (still) be in the classroom. Ideas about uncertainty of science, the views of science as an unchallenged authority or as a given body of knowledge, have all shifted in recent times as the concept of authority itself has altered. The rhetoric of public engagement has led to increasing attention being given to ways of involving the general public in scientific issues. This was summarized by the UK Research Councils (2002, p. 3):

> With the increasing recognition that dialogue and multiple inputs are crucial factors in underpinning sound decision-making in science, it has become accepted that two-way communication is a more robust way to address [this].

Research in science communication is therefore broad-based, since effective engagement requires contextual understanding of issues such as appropriate framing, belief, knowledge, cultural influences, and perceptions of risk. Of necessity, such research incorporates multidisciplinary approaches drawn from the sciences, the arts, and the humanities.

Cross-References

- ▶ Public Communication of Science and Technology
- ▶ Public Engagement in Science

References

Burns TW, O'Connor DJ, Stocklmayer SM (2003) Science communication: a contemporary definition. Public Underst Sci 12:183–202

Research Councils UK (2002) Dialogue with the public: practical guidelines. Research Councils UK, London

Stocklmayer SM, Bryant C (2012) Science and the public – what should people know? Int J Sci Educ Sci Commun Engagem 2:81–101

Science Community Outreach

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Keywords

Community based; Identities; Role models

The mantra of "science is all around you" echoes through a multitude of classrooms and textbooks. However, as our youth step out of their schools every afternoon, there is frequently very little evidence of the value placed by society on science in their communities, and little connection is made between the science curriculum learned at school and student identities as they participate in their everyday life activities. Community-based science programs bring science to the neighborhoods in which the youth live and allow community members access to a wide range of scientific processes in familiar settings. They can be powerful experiences for all if they are well designed and situated.

Science practitioners, ranging from gardeners, farmers, and chefs to engineers and doctors, have science concepts and skills embedded in their daily tasks. When communities are able to highlight the relationship between these activities and science, community members who participate in such events stand to gain an appreciation of the value of science as well as the diversity of scientific understandings and their applications. Further, the fact that community members are involved in such presentations points to the feasibility of local people enjoying a relationship with science. The power of local role models can be great. Finally, because parents, particularly mothers, can engage in such programs, it is extremely valuable from a science education standpoint, since their influence on their sons' and daughters' academic interests is known to be strong.

An illustrative example of a science-related community-based program is the Contact Science program, launched in Texas in 2010 with the goal of bringing a set of diverse, engaging, and interactive science experiences to various communities in the Dallas Fort Worth Metroplex. It is the brainchild of Russell Hulse, Nobel Laureate in Physics, located at the University of Texas at Dallas. At the heart of the program were the design, construction, and placement of adventure stations around various themes in public libraries. These stations functioned as miniature lab benches and had real science tools as part of them. For example, the Electrical Adventures station included an oscilloscope and all the various components to allow for a wide range of experimentation with electricity; the Microworld Adventures Station included a high-end light microscope, as well as a "scope on a rope" that allowed users to look at a monitor to get close-up views of their skin, a leaf, clothing, or anything of interest. Each station had a computer guide with step-by-step experiments for the user to start off with, or the user could play with the components independently and truly experiment as they wished. Each station was designed so that it was convenient for the libraries to rotate the theme and materials every few months. The bench or base unit would stay at the library, but the oscilloscope and other equipment could be removed and easily driven over to a different library. In this way a group of libraries could get a new exhibit every few months. The key strategies used by Contact Science were, firstly, partnering with a system that was already designed to serve local communities, i.e., public libraries, and, secondly, focusing program experiences around authentic scientific tools. To this latter end, staff at the University of Texas at Dallas worked with the Science Museum of Minnesota, an institution that designs and fabricates exhibits for museums around the country. A good match was perceived between some of the lab bench-like exhibits that were on the museum floor and the nature of science activities to be placed in communities around the university. A productive working relationship emerged with Contact Science, with the collaborative adaptation of three of the museum's existing small, interactive exhibits for use in the community-based pilot program. Further, since the program was housed in a university, there was a natural partnership with university resources, particularly access to university student volunteers who would assist in providing additional programming, such as robotics workshops that were also held at these libraries, as well as to students and faculty who were interested in extending the reach of the adventure stations by adding demonstrations and facilitation. Involvement of these three different institutions (library, university, and museum) required considerable learning and working around the varying cultures of these spaces. However, the effects of using the resources present in each institution collaboratively in bringing thoughtful science educational experiences to communities made this a worthwhile effort.

Communities that are able to identify their science-rich resources and create spaces for people to come together to participate in various science-related activities stand to gain a population who can identify the ways in which science is relevant, interesting, and useful. Community spaces and groups such as public libraries, boys' and girls' clubs, girls' scout troops, and recreation centers have the advantage of a pattern of frequent and repeat visitation, unlike informal learning spaces such as museums. This allows for repeated engagement in science programs housed in these spaces, in contrast to the "hit and run" science that frequently occurs in informal learning spaces to which regular visits tend not to occur. Partnerships between institutions, such as museums, research centers, community spaces, and schools, can allow for the design of relevant, conceptually rich, tool-based science experiences designed to incorporate multiple entry points. Involvement by community role models, such as university and high school students and other professionals living in the community who volunteer as explainers or in other ways interact with users, can augment the power of such community-based science outreach experiences.

Cross-References

- ▶ Citizen Science
- ▶ Hobbies
- ▶ Lifelong Learning
- ▶ Science Circus
- ▶ Science Museum Outreach

References

Lave J & Wenger E (1991) Situated Learing: Legitimate Peripheral Participation. Cambridge University Press

Wenger E (1998) Communities of Practice: Learning, Meaning and Identity. Cambridge university Press

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Science Curricula and Indigenous Knowledge

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Keywords

Science Education in the Non-West

Curriculum can be thought of as what is required to be taught, its scope and sequence. This is usually in the form of documentation prepared by an educational authority to be used in schools and colleges under its auspices. In recent times some of this work has been done at a national level by agreement with state, provincial, and local educational authorities (where they exist) which may then modify and enact the curriculum within their domains. In some cases the curriculum may be prepared by recognized external agencies such as the International Baccalaureate. The curriculum differs from individual teacher's or school-based programs which are interpretations of the curriculum for individual school or classroom contexts. Universities usually prepare autonomous curricula although there are usually processes nationally and internationally to ensure comparability.

A related interpretation of curriculum refers to curriculum resources, a classroom resource which may have been developed by the educational authority, by an interested organization, or often by groups of teachers to implement the curriculum. Curriculum resources are usually considered to be a link between the curriculum and the classroom pedagogy; however, resources may be developed which are not based on the curriculum or reflect a particular interpretation of its meaning. Textbooks can also be considered as curriculum resources which should reflect the curriculum.

There has been some discussion of the inclusion of indigenous knowledge in the science curriculum in recent times, although previously there have been instances of the inclusion of indigenous knowledge in some ways, most frequently in textbooks. Critiques of this portrayal have focused on stereotypes which denigrate indigenous peoples and their knowledges. There has been advocacy for the inclusion of indigenous science in mainstream science courses primarily since the 1990s, and terminologies such as multicultural science and multi-science have been used by the advocates. This has been undertaken by both indigenous and non-indigenous scholars (including Aikenhead, Jegede, George, Kawagley, Cajete, Snively and Corsiglia, Stanley and Brickhouse, Cobern, Pomeroy, and Ogawa). Criticism of these approaches has been mainly made by a group of science philosophers who make a distinction between the universality of Western modern science as core science and the lesser position of indigenous knowledge and indigenous sciences. However, this argument has in some ways been circumvented in some countries where educational authorities have mandated the inclusion of “indigenous perspectives” across the curriculum, including the subject science. Other arguments include approaches to redefine Western modern science to be inclusive of indigenous knowledge (particularly approaches to African science).

Science and Indigenous Knowledge

Since the Rio Earth Summit in 1992, there has been an increasing recognition by some professional scientists of the role of indigenous knowledge, particularly in areas involving land management and the environment. At the UNESCO World Conference on Science for the Twenty-First Century, in 1999, there was a call for a wider use and support for traditional forms of learning and knowledge, as well as cooperation between holders of traditional knowledge and scientists to explore the relationships between different knowledge systems and to foster interlinkages of mutual benefit. As a consequence, in 2002 the International Council for Science (ICSU) prepared a report on science and traditional knowledge. It was pointed out by a subcommittee that traditional knowledge was informing science, particularly in nature management. They recommended that the ISCU and member nations should sustain traditional knowledge systems through active support to the societies that are keepers and developers of this knowledge, promote training to better equip young scientists and indigenous people to carry out research on traditional knowledge, and promote and develop research to better appreciate traditional knowledge. Just prior to the Rio+20 UNESCO conference in June 2012, an ICSU session on indigenous knowledge noted that indigenous and traditional knowledge has gained increasing recognition as an essential building block for global sustainability, as well as a change in relationship between scientists and indigenous knowledge holders. A shift away from the notion of scientific validation of extraneous knowledge and its integration into science was leading toward an approach anchored in the codesign of research and the coproduction of new knowledge to address complex emerging challenges. Diverse knowledge systems were becoming more valued because of the benefit of place-based knowledge systems of heightened local relevance.

Areas of knowledge production which have seen the interaction of Western scientists and their indigenous counterparts include (to use their Western names) ethnobotany and ethnobiology, archeoastronomy, and agriculture. These interactions have seen the exchange of knowledge by both groups of people in a variety of ways, including elders from both groups. This exchange is limited to fields of knowledge where some similarity occurs and varies because of the place-based nature of indigenous knowledge. Often the knowledge is referred to as indigenous science or a way of knowing or, if it is more specifically environmental, as traditional environmental or ecological knowledge (TEK). Occasionally the location of the knowledge will be specified, such as Maori environmental knowledge or the Yupiaq way of knowing. Thus, there is an attempt by some professional Western scientists to broaden the definition of science to become more inclusive of place-based indigenous sciences.

Some researchers in science studies have considered that although indigenous knowledges had lacked "the same authority and credibility as science because their localness restricts them to the social and cultural circumstances of their production" (Watson-Verran and Turnbull 1995, p. 116), there was now an explicit focus on the local as an implicit basis of scientific knowledge. It has been suggested that the ways of understanding the natural world that have been produced by different cultures and at different times should be compared on an equal footing. Such epistemological relativism was rejected by other science studies researchers. Although Western science could be considered to be a localized knowledge system, as are other ethnosciences, the notion that they are equally defensible was rejected. The standpoint approach was that different cultures' knowledge systems have different resources and limitations for producing knowledge.

Others who were researching indigenous knowledge and education considered that it was possible to produce a transformative science which would highlight the differences and complementarities between Western science and indigenous ways of knowing. Some wished to initiate "a conversation resulting in a critique of Western science that leads to a reconceptualization of the Western scientific project around issues of multiple ways of seeing, justice, power, and community" (Semali and Kincheloe 1999, p. 45). Their idea of an indigenously informed transformative science is not simply an addition of knowledge but "challenges the epistemological foundations of ethnoknowledge known simply as science" (p. 45). They also suggested that indigenous knowledge could transform education and that its inclusion in the curriculum leads to a needed interaction with "difference" for Westerners, leading to a heightened consciousness which is more empowering than "a narrow focus on homogeneous cultural traditions" (Semali and Kincheloe 1999, p. 47).

Science Education and Indigenous Knowledge: Multicultural Science Education

In the past twenty-five years, there has been much research in education in general and in science education in particular into indigenous ways of knowing. Multicultural science educators questioned whether the Western knowledge base was appropriate or culturally biased, specifically questions such as: "Whose culture are we teaching? Whose knowledge is of most worth? Who benefits and who is harmed by current approaches to curricula?" (Stanley and Brickhouse 1994, p. 387). It was suggested that holding a universalist position with regard to scientific knowledge gave a feeling of omniscience to scientific knowledge and has led to the destruction of other knowledge systems regarded as inferior by Western standards. What was advocated was a community of learners with "the capacity to generate and consider various possibilities for understanding and determining knowledge" (Stanley and Brickhouse 1994, p. 394). This was seen to lead to a science education from multiple perspectives rather than one perspective, although these other perspectives should not be given equal weight in the curriculum. Later, concern was expressed that universalist Western modern science could be taught as if it was neither controversial nor problematical and that multicultural education introduced students to new ways of thinking about the natural world helping them to understand not only other ways of thinking but also some of the fundamental understanding of Western ways of thinking.

The relationship between Western modern science and indigenous science, particularly traditional ecological knowledge, has been discussed in the context of science education. The local nature of traditional ecological knowledge and its transmission were considered as an oral narrative, and its place related to sustainable development. The relativist nature of indigenous science is a reflection of its local applicability, in contrast to the universalism of Western modern science. The spiritual base of traditional ecological knowledge is also seen as an impediment for it being considered as science by many Western scientists. What seems to be forgotten is that most indigenous sciences are accumulations of observations, refined over time, what is referred to often as "the wisdom of the elders." Other science educators suggested that Western science could be defined with sufficient clarity so as to maintain a coherent boundary for the practical purposes of school science curriculum, using the standard account for science, and that the boundary would exclude indigenous knowledge as well as other domains of knowledge. It was suggested that it would be better considered as a different kind of knowledge, valued for its own merits. From such a position it could maintain its independence from which it could critique the practices of science rather than be co-opted into a universalist science. Some indigenous science educators have seen the inclusion of indigenous education as being important, particularly in providing a more culturally relevant frame of reference for teaching science to indigenous students. Others, noting that teaching of science is mostly by Western teachers, were concerned that the treatment of indigenous knowledge would be oversimplified and essentialized to the point of becoming a caricature of its reality.

The incommensurability of multiculturalism and universalism was examined in the context of traditional ecological knowledge and Western science. It was pointed out that "the reduction of local contexts [of TEK] to scientific praxis is inherent to the transcendent nature of scientific knowledge and includes a loss of local heterogeneity, dynamic, and plurality; and transcendent scientific knowledge is useless unless local contexts are reduced to the conditions of scientific laboratories rather than remaining contexts in their own right" (van Eijck and Roth 2007, p. 18). It was concluded that traditional ecological knowledge and Western science were different but were useful in specific local contexts and that traditional ecological knowledge could relate to students learning to solve local problems.

On the other hand, there has been a negative response from a group of Western scientific philosophers critical of multicultural science, including traditional and indigenous sciences, and its influence on the science curriculum. The universalist position advocated mainstream Western science and was critical of multicultural science, particularly a form referred to as "robust" or "noninterventionist multiculturalism." Robust multicultural science was considered by these critics to be relativist and promoting equally validity with universalist Western science. A version of multicultural science termed "epistemic multiculturalism" was also considered incompatible with universalist science. Here multiculturalists were criticized in particular for attempting to broaden the notion of science to include ethnosciences, traditional ecological knowledge, and indigenous knowledges. In considering whether indigenous knowledge or traditional ecological knowledge should be included in the school science curriculum, a version termed "limited compatibilism" was proposed. By this was meant whether there were sufficient similarities between the indigenous knowledge and Western science, normally judged against Western science.

What is notable in the discussions of both the scientists and the science educators who are involved is the emphasis of place-based and local knowledge in the indigenous sciences and traditional ecological knowledge. How to implement this sense of the local through the curriculum and then into pedagogy is one of the difficulties being addressed by some multicultural science educators.

Science Curricula and Indigenous Perspectives

In the later part of the twentieth century, many countries reappraised their school curricula and developed national goals for education. In several of the settler states – those countries which had been colonized particularly by European countries but which had since become independent – the national goals included references to the original indigenous inhabitants. This occurred both in countries with a majority population of mostly European origin such as Australia and Canada and in those with a native majority such as South Africa. An outline of the Australian experience in endorsing indigenous perspectives is summarized here.

The first attempt to develop national goals for school education in Australia was at the end of the 1980s and was called the Hobart Declaration. Although education in Australia is controlled at the state or territory level of government, the federal (national) government is concerned with issues of quality of education across the nation. In a national project funded by the Ministerial Council for Education ministers, a series of agreed goals of education – the Hobart Declaration – was reached. These were to inform development of national curriculum across the eight identified curriculum areas, including science, as well as identifying a number of cross-curriculum perspectives. Item 8 read: "To provide students with an understanding and respect for our cultural heritage including the particular cultural background of Aboriginal and ethnic groups." The reference to Aboriginal culture was interpreted as applying in the teaching and learning of science and needed to become evident in science curricula developed nationally; it became commonly referred to as the "indigenous perspective."

The Hobart Declaration has been updated on two occasions, as the Adelaide Declaration (1999) and the Melbourne Declaration (2008). The Melbourne Declaration included providing students with an understanding and respect for their cultural heritage including the particular cultural background of Aboriginal and ethnic groups and giving all students the opportunity to access indigenous content where relevant. As well, within the goal of promoting equity and excellence, it included ensuring that schools build on local cultural knowledge and experience of indigenous students as a foundation for learning and work in partnership with local communities on all aspects of the schooling process, including to promote high expectations for the learning outcomes of indigenous students. This represents a shift through the declarations from solely consideration of indigenous knowledge to ensuring inclusion of indigenous peoples in all aspects of the schooling process.

There have been attempts to develop a national curriculum including science in Australia since the 1990s, and although its implementation by the various states and territories has been varied, these attempts have influenced the science curriculum in all jurisdictions. Its latest form is the National Curriculum: Science released by the Australian Curriculum Assessment and Reporting Agency in 2011, which covers the years from Foundation to Year 10. A cross-curriculum priority in the national curriculum, including science, is termed "Aboriginal and Torres Strait Islander histories and culture," although it is commonly referred to as the indigenous perspective. Indigenous perspectives in the science curriculum are incorporated as possible elaborations in the Science as a Human Endeavour strand rather than the Science Understanding strand. This has been seen by some commentators as continuing to treat indigenous knowledge as inferior to Western science knowledge. Some science educators have suggested that the discussion regarding the nexus between indigenous science and Western science could be treated as relating to the nature of science, which is implicitly within the realm of Science as a Human Endeavour strand in the Australian curriculum.

Similar processes incorporating indigenous perspectives into the science curriculum can be noted in the recent curriculum development in a number of countries, particularly Australia, New Zealand, Canada, and South Africa. Thus, it can be seen that the imperative to be inclusive of indigenous culture and knowledge has been taken up by curriculum authorities.

It has been advocated that indigenous science should be included in the science curriculum, for a number of reasons. Indigenous science could be seen as part of the way we can understand the world. Secondly, indigenous science could tell us something about Western science and science education. Finally, it was a way of achieving reconciliation between indigenous and non-indigenous peoples and a vehicle for social justice. Earlier, indigenous perspectives were perceived primarily as impacting on non-indigenous students. However, as seen in the commentary on the Melbourne Declaration, they have evolved to impact on the education of indigenous students. This included trying to reconnect indigenous learners with their roots and developing cultural citizenship, as well as expanding our knowledge base in a knowledge society.

The new South African science curriculum prescribes the inclusion of indigenous knowledge, allowing for localized content and accommodating different ways of learning although it is not always clear what this means. In common with curriculum documents in other countries, what is often described as indigenous knowledge are fragments which fit with Western science, compatible with the notions of oversimplification, caricature, and essentializing treatments suggested by some science educators but perhaps a pragmatic implementation of limited compatibilism also. However, there has been a call for indigenous knowledge to be included in Western science in several parts of Africa by a number of African science educators, both indigenous and non-indigenous (including Jegede, Ogunniyi, Semali, Okebukola, Gitari, Keane, and Malcolm), a call which resonates with that made by African scientists as well.

The development of a Maori science curriculum, *Putaiao*, in Aotearoa, New Zealand, in the 1990s, has offered a precedent for similar curriculum development elsewhere. In writing the Maori science curriculum, the Western science curriculum was reconstructed to match up with Maori understandings of the world; much of the Planet Earth and Beyond strand, in the Maori version, has gone into the Biological World strand, which was renamed *Mataora*. What is important for Maori it that this represents the joining of *Papatuanuku* (earth) with the rest of living things (as defined through science). However, there are a number of conditions imposed which limited the accessibility of students to the curriculum. Firstly, the document is written in Maori, for students who are learning through the medium of Maori. Secondly, there were issues regarding language at two levels. At one level there were differences which are apparent with the syntax construction between native speakers and second language learners of Maori. Then there were issues of a “standardized” Maori language in a country made up of various tribal groups with differing dialects.

From time to time indigenous influences on science curriculum have been put aside. In Hawaii a science standard called *Malama I Ka ‘Aina* was adopted in 1994. It incorporated an awareness of Native Hawaiian phenomena and supported culturally responsive, place-based curriculum. However, it was removed in 2005 on the recommendation by out-of-state consultants because it was seen as being too limited to Hawaiian culture, suggesting the political challenges to forms of multicultural science education were not completely aligned with mainstream perspectives.

There appears to have been limited critique of the role of the education authorities in implementing indigenous perspectives. One criticism would come about from the assumption that indigenous and Western knowledges run parallel, when they have been shown by a number of scholars that they have different characteristics. A second, related criticism would apply because the authorities subdivide indigenous knowledge according to the Western fields of knowledge, including science. As noted about, in school science curricula, there has been a tendency to fit the indigenous perspectives into the Western science curriculum structure. This has led to a simplification of the indigenous knowledge to the point of caricature.

Conclusion

There have been two approaches to the inclusion of indigenous knowledge in the school science curriculum. The first of these is by scientists working close to indigenous peoples who see indigenous knowledge as valuable, particularly as local knowledge. One of their strategies is to expand the definition of Western science so that it can include indigenous knowledges in a respectful way. They are supported by a group of multicultural science educators who also wish to be respectful of indigenous students' prior knowledge. The idea of expanding the definition of science and inclusion of indigenous knowledge in the school science curriculum is opposed by some philosophers of science. Separate from this and somewhat preemptive of the work by scientists and science educators is a move by many educational authorities to include indigenous knowledge across the curriculum, often referred to as indigenous perspectives. This includes in the science curriculum although it seems that often it is not clear what an indigenous perspective means. What is becoming clear from science, science studies, and cultural studies in science education is that indigenous knowledge incorporates a local perspective that complements the science one.

Cross-References

- ▶ Indigenous Knowledge Systems and the Nature of Science
- ▶ Indigenous Students
- ▶ Multiculturalism
- ▶ Science Curricula and Indigenous Knowledge
- ▶ Teacher Preparation and Indigenous Students

References

Semali LM, Kincheloe JL (eds) (1999) What is indigenous knowledge? Voices from the academy. Falmer Press, New York

Stanley WB, Brickhouse NW (1994) Multiculturalism, universalism, and science education. Sci Educ 78:387–398

van Eijck M, Roth W-M (2007) Keeping the local local: recalibrating the status of science and traditional ecological knowledge (TEK) in education. Sci Educ. doi:10.1002/sce.20227

Watson-Verran H, Turnbull D (1995) Science and other indigenous knowledge systems. In: Jasanoff S, Markle G, Pinch T, Petersen J (eds) Handbook of science and technology studies. Sage, Thousand Oaks, pp 115–139

Science Departments

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Keywords

Head of department; Secondary science department; Subject department

The science department as a unit within secondary or high schools began to emerge in the mid-nineteenth century. Arising from the increasing differentiation of knowledge that accompanied the Industrial Revolution, the development of departments was intrinsically linked both to the prevailing sociopolitical forces of the time and to the rising status of the academic disciplines. As Layton (1973) notes, prior to the professionalization of science and the development of the department as an organizing feature of secondary schools, science education was heavily influenced by a concern for working from the concrete to the abstract. One of the most influential science educators of the time, Richard Dawes, was concerned that students should initially engage with science through the common things they saw around them and from this interest work toward scientific explanations of phenomena. His efforts were highly successful, to the extent that Dawes took on the role of instructing his teachers, and their apprentice teachers, in both scientific principles and the application of his teaching strategies.

The early rise of the science department is closely linked to the professionalization of science, a movement largely driven by William Whewell and the British Association for the Advancement of Science. Whewell argued that science, as a discipline, should be taught in an abstract form and should serve the goal of "mental training." It was believed that only the upper classes were capable of the "mental training" required by the high-status, abstract, academic disciplines, while the lower classes were only capable of simple, concrete thought. Secondly, the newly professionalized scientists worked to secure status, and hence resources, for themselves and their discipline, especially within universities. Academic disciplines accrued to themselves control over both content and the entry requirements to their discipline. Importantly, the universities were given the power to set entrance examinations, a move that was to have profound implications for teaching and learning in schools.

In order to accommodate the demands being placed on them by the universities, schools began to adopt standardized systems of timetables, lessons, and school subjects. The organization of school subjects reflected the university disciplines. This development began in Britain in the 1850s and was basically completed there in 1917 with the establishment of the School Certificate that defined both content knowledge and the evaluation of that knowledge and established preferred teaching strategies, for university preparatory subjects such as Botany, Physics, and Chemistry. This pattern was repeated across the British Empire and in the United States, where the Committee of Ten also expounded the virtues of "mental training." In schools, these subjects were to be taught by content specialists who could meet the expectations of the examinations. These content specialists were to form the first school subject departments. Science was seen as a specialist activity; hence there was little effort to develop the pedagogical skill of the teachers. Consequently, the role of the department was principally administrative, charged with ensuring that university entrance standards were met. The first modern usage of the term department was in 1905, and by the 1920s, secondary teachers in Western countries were being educated in the university disciplines, a development that reinforced the bonds between the discipline and the department. This strong historical link between the discipline and the subject is an important feature in understanding the function and power of the contemporary school department.

In the first half of the twentieth century, major demographic changes occurred in Western countries, in the form of mass immigration, increasing urbanization, and major changes in child labor laws. The huge increase in the public secondary school population, together with the loss of influence of the "mental training" view of education, profoundly changed the work of the department. While still seen as subject specialists, departments took on an increasing responsibility for pedagogy, supervision, and administration. In the 1950s, academic research began to focus on the potential importance of the department for improving the quality of science education. Research at this time suggested departments should maintain a simultaneous focus on supporting students, while also maintaining links to their associated academic, professional, and school communities. This research focus has developed sporadically over the past half century.

Siskin (1994) has defined four aspects of the school-based subject department that she believes are crucial to the delineation of the subject department in contemporary American high schools. The department, according to Siskin:

> . . . represent[s] a strong boundary in dividing the school . . . provide[s] a primary site for social interaction . . . [is] an administrative unit, [with] considerable discretion over the micro-political decisions affecting what and how teachers teach, and as a knowledge category influences the decisions and shapes the actions of those who inhabit it. (p. 5)

Working from these aspects and reflecting their evolution, science departments possess two concurrent functions within the school: the social and the organizational (Melville and Wallace 2007). The social function is a powerful one; within departments (particularly in high-status subjects such as science) teachers are socialized into what is important in their subject content, how it should be taught, and why it should be taught. This socialization shapes, and is shaped by, teachers who identify themselves primarily as teachers of science. This identification is founded on their university education in the sciences, an understanding of the language of science, and a common view of the place of science in society and education. In terms of professional learning, a shared sense of identity is foundational to the work of effective departments, as it allows teachers to trust the judgment and abilities of their colleagues and be prepared to learn from each other. Trust facilitates access to other's knowledge, for example, about content, pedagogy, and the relation of science to society.

The social function is foundational to the organizational function of departments, for their organizational power lies in the capacity to influence how and what teachers teach. Teachers educated into a discipline will generally replicate the academic traditions of that discipline; this is a principal reason why secondary teachers maintain their own practices in the face of efforts to reform teaching and learning (cf., Carlone 2003). Taken together, the social and organizational functions of departments give them tremendous political power with which to arbitrate their response to reform efforts. The members of a strong department may achieve an organizational consensus about what is important in their subject, with the important caveat that within science, teachers can, and will, disagree about the nature of the discipline and, hence, what constitutes "good" teaching. Such a consensus (if developed) is important for ongoing professional learning, as it allows for the establishment of clear goals for student learning. The establishment of consensus cannot, however, be assumed for departments, and there is always the risk that the consensus may be to not change what has "worked" in the past.

Traditionally within departments, the role of leadership has been the preserve of the officially designated, middle management, head of department (or chair in North America). Aside from the established concern for pedagogy, supervision, and administration, Brundrett and Terrell (2004) note that the role is increasingly perceived as being:

> Moral and . . . political . . . because it involves the creating, organising, managing, monitoring and resolving of value conflicts, where values are defined as concepts of the desirable . . . and power is used to implement some values rather than others. (p. 17)

Within the literature on departments, the notion of teacher leadership is being given increasing prominence. Teacher leaders simultaneously undertake and model their own professional learning, while working to build a culture of collaboration that benefits students. Such leadership requires the capacity of teacher leaders to function effectively across departments as both communities and organizations, for, in doing so, they can influence three key reform areas: to provide leadership in the promotion of teaching and learning of science, to develop learning opportunities, and to establish a capacity for reform (cf., Yager 2005).

Cross-References

- ▶ Communities of Practice
- ▶ History of Science
- ▶ Identity
- ▶ School Environments
- ▶ Secondary Science Teacher Education

References

Brundrett M, Terrell I (2004) Learning to lead in the secondary school: becoming an effective head of department. RoutledgeFalmer, London

Carlone HB (2003) Innovative science within and against a culture of 'achievement'. Sci Educ 87(3):307–328

Layton D (1973) Science for the people. George Allen and Unwin, London

Melville W, Wallace J (2007) Metaphorical duality: high school subject departments as both communities and organizations. Teach Teacher Educ 23(7):1193–1205

Siskin LS (1994) Realms of knowledge: academic departments in secondary schools. The Falmer Press, London

Yager RE (2005) Achieving the staff development model advocated in the national standards. Sci Educ 14(1):16–24

Science Education in Iran

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Keywords

Science Education in the Non-West

Iran's history as one of the oldest empires dates back to the seventh century BCE. Iranians were mainly Zoroastrians and considered themselves Aryan Persians. Over the pre-Islamic period, instruction in reading, writing, mathematics, medicine, and astronomy was accessible to privileged higher social classes. The wars between Arab Moslems and Persians brought the Old Iranian (Persian) Sassanid Empire and its central government to an end in the seventh century CE. The influence of Islam on Iran changed not only the political climate but also cultural worldview of Persians. Islamic teachings such as monotheism, justice, brotherhood, and equality for all human beings have influenced the Iranian mind.

After the arrival of Islam, Iran's history witnessed much social and political upheaval. Historians of Iran mention the tenth and eleventh centuries as the first golden age of scientific and social development (Nasr 2009). Iranian Moslem scientists extended the frontiers of science based on an inductive-deductive approach. Rhazes, Avicenna, Jabir ibn Hayyan, Biruni, and Kharazmi were among the Iranian scientists whose works were translated into Latin during Medieval and Renaissance periods, paving the way for scientists to build modern experimental sciences. The Moghul invasion in the thirteenth century, in contrast, triggered the fall of science in Islam and Iran. During the Shia Safavid period (sixteenth–eighteenth centuries), however, there was a second rise of scientific advancement (Velayati 2007).

Impacts of Social and Cultural Context

The rulers of Iran in the first half of the nineteenth century, after a number of military defeats, concluded that the weaknesses of the country needed to be addressed through the establishment of a modern educational system. Students were dispatched to European universities and the Dar-al-Fonun (polytechnic) was established at home in 1871. The Dar al-Fonun was the first modern college in Iran. At Dar al-Fonun, medicine, pharmacy, military studies, and engineering were taught by European teachers. Modernization of Iran's education system was based on the translation and adoption of Western knowledge and institutions. The use and adaptation of materials and technical and institutional developments without accepting the West's intellectual and cultural system was and still is problematic (Ringer 2013). The question is how to be modern without losing Iranian identity and integrity. Different answers based on different cultural and political directions have been offered for the question. During the Pahlavi dynasty (1926–1979), for instance, modernization followed secularization and centralization of education, with great emphasis placed on Aryan pre-Islamic identity. However after the Islamic revolution of 1979, the centralization continued but the Shia Islamic identity was underscored.

Directions

Education at Dar al-Fonun was elitist, the aim being the education of students for future government employee positions. However, education in the late nineteenth century, when early elementary schools were established, was mainly based on nationalism. The aim was the education of citizens. The discontinuity and lack of proper harmony between preuniversity and university education and the lack of an organic relationship with the work market have influenced science education in Iran. Iran's oil-dependent economy has hindered the attempts to surmount the disharmony. Not only has the governmental oil-reliant economy been a crucial factor in the persistency of the gap between education and the labor market but also a serious barrier to developing a knowledge- and technology-based economy. The two universal directions, preprofessional training and science education for citizens, have affected science curriculum in Iran. Likewise the Iranian Islamic worldview and a different cultural interpretation of science from the West have had a crucial impact. Iranians debate the nature of Islamic science and its relationship to science in general (Golshani 2004).

The orientation of science education in the new national curriculum of Iran is expressed as follows: comprehensive and holistic growth of students based on the assumption that acquiring knowledge in itself is a spiritual attempt that leads to a more profound and teleological understanding of the created universe and consequently to attain monotheistic insight as a component of the "good life" (*Hayat e Tayebeh*). However, in practice, the two following ideological trends are more noticeable: (1) preparation of students for entrance to universities in order for them to find their jobs in science and technology or governmental positions that lead to higher social status and (2) preparing students who do not want to have any profession or job related to science and technology but need to adapt themselves to a society that is increasingly getting dependent to science and technology.

Intended Changes

Since the late nineteenth century and with the expansion of new schools, policy makers and the general public have always paid attention to and facilitated qualitative and quantitative growth in science education**.** Changes in formal science curriculum can be classified roughly into six periods:

First period (late nineteenth century–1942): Prior to the nineteenth century, Iran had no specific aims and content for science curricula. Teachers would organize their teachings based on their own personal views. Mirza Ali Khan-e Moallem in 1911 and Mohammad Tadayon Birjandi in 1912 were the first textbook authors for the 5th and 6th grades. These books promoted the teaching of pure science. In 1912, a system of 6 years of compulsory education followed by another 6 years of non-compulsory education was enacted. Subsequently science curricula which included a list of syllabi for the two 6-year programs were designed, and a series of pedagogic principles were passed by the Ministry of Education. The syllabi contained content differences with respect to gender roles based on traditional Iranian society. Teachers taught content following predetermined principles. Gradually teachers were allowed to choose from a list of government-approved textbooks. In 1930, for the first time, the Ministry of Education published elementary textbooks and 10 years later published textbooks for high schools. These textbooks, called Vezarati (ministerial), were written by a team of university professors and experienced teachers. Although these textbooks were of fine quality and were welcomed by teachers, due to financial difficulties, the government was unable to publish and distribute them throughout the country. Therefore teachers were free to use Vezarati textbooks or pick from other textbooks.

Second period (1943–1967): Due to political and economic disorders caused in part by the Second World War, there was little planning or management of science education by the Ministry of Education during this period. All science curriculum development activities were surrendered to the free market. Although the competitive atmosphere motivated many to do research and develop science curricula, lack of guidance and supervision led to disorder in school science. In1963, Iran's Textbooks Organization was established and became the exclusive agency in charge of publication of textbooks. Dr. Mahmoud Behzad, the first director of the organization and the author of several science textbooks and teacher's guides, improved school science (Mo'tamedi 2012).

Third period (1968–1980): During this period, public compulsory education was increased from 6 to 8 years and the educational system changed to 5 + 3 + 4 model. Science was made compulsory at all grades. The aims of science education broadened and were influenced by science education in the USA. During this period, government political influence increased, and education became more centralized and was expanded. Returning to the practice of earlier periods, teachers were required to implement an official curriculum.

Fourth period (1981–1995): In the early years after the Islamic revolution, due to the heavy content load and teachers complaints, the content volume of science education slightly decreased. Parts of some science textbooks were revised to remove positivistic ideas. All in all the importance of teachers' role in science education and new science teaching methods were highlighted. Teachers who were found to be committed to Islamic teachings were selected to underline the Islamic values. Shortage of qualified science teachers as a result of economic difficulties, caused by the Iraq-Iran war, was noticeable in this period.

Fifth period (1996–2010): During this period, new science textbooks and teacher training curricula stressed constructivist approaches, collaborative learning, hands-on minds-on activities, descriptive evaluation, and content relevance for all grades. The educational material and information and communication technology were used to support teachers and learners. Research was emphasized, and some efforts were directed toward the development of theoretical indigenous science and also science education (Bagheri Noaparst 2011, Golshani 2004).

Sixth period (since 2011): In recent years, Iran has adopted a new philosophy of formal education and a reform of the national curriculum is being planned. Integration among different disciplines, attention to real-life interests, and educating creative and responsible students are among the main concerns. Science education in elementary and lower secondary grades is being redesigned, using a thematic approach with integrated learning activities. Upper high school education is based on separate disciplines. Promoting the professional position of teachers and a decrease in centralization are among the formal plans.

Cross-References

- ▶ Epistemology
- ▶ Humanist Perspectives on Science Education
- ▶ Indigenous Knowledge
- ▶ Values and Indigenous knowledge
- ▶ Worldview

References

Bagheri Noaparast K (2011) An introduction to philosophy of education in Iran, vol 2. Elmi va Farhangi, Tehran

Golshani M (2004) Issues in Islam and science. Institute for Humanities and Cultural Studies, Tehran

Mo'tamedi E (2012) The history of physics education in high school of Iran, 3rd edn. Loh-e Zarin, Tehran

Nasr SH (2009) Islam, science, Muslims and technology, Islamic Book Trust, Kuala Lumpur

Ringer MM (2013) Education, religion, and the discourse of cultural reform in Qajar Iran, 2nd edn. Mazda, Costa Mesa

Velayati AA (2007) Dynamism of Islamic and Iranian culture and civilization. Foreign Ministry Affairs, Tehran

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Science Education in Mainland China

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Keywords

Science Education in the Non-West

Introduction

The last three decades have seen a tremendous transformation of school science education in mainland China in terms of provision and access, curriculum and pedagogy, and assessment. In addition, there has been major transformation in science teacher education. In part these reforms of science education have been in response to international science education trends and reforms which have provided impetus and influence as the Chinese government has continually followed the policy of reform and opening up to the world. And in part the reforms arise from the rapid social changes that have taken place in the realms of Chinese economy, politics, and social life (Wei 2008).

As is the case with schooling in general within mainland China, it is generally recognized that Chinese science education has had little visibility internationally. This is most likely because of the lack of science education research done by Chinese science educators who can publish in major international journals of science education. In this entry, I provide readers with an insider's perspective. First, I give some background by highlighting the historical overview of science education in China. Second, I present a description of recent reforms of school science education reforms in mainland China. Finally I conclude with a summary.

Historical Background

Although modern science first came to China from the West with the Christian missionaries, initially in the late Ming dynasty and then in the late Qing dynasty (Wang 1997), it was in the first part of the twentieth century that the first generation of Chinese scientists who trained in the West grew up and worked in Chinese universities and research institutes (Wang 2002). The following facts clearly show that it was only a twentieth-century phenomenon for modern science and science education to establish themselves in China. The first national university, Peking University, was founded in 1898 by the Qing dynasty government, while the first modern school system was borrowed from the West by patterning from that of Japan in 1904. The first science society, i.e., the Science Society of China, was set up in 1915 by a group of Chinese overseas students studying science and technology in US universities (Wang 2002), and the Academia Sinica, modeled after the French and Soviet systems, was established in 1928, just a year before the nationalist government was established in Nanjing under Chiang Kai-shek.

Twentieth-Century Influences on Science and Science Education in China

In observing the history of modern science and science education in China, I use five lenses to put science education, formal and informal, in perspective: the nationalistic, the political, the linguistic, the cultural, and the pedagogical.

First, the nationalistic lens informs us that modern science and science education as imported culture from the West have been welcomed and embraced by Chinese people. Essentially this is because it is believed science and science education will rejuvenate and strengthen a China that has lagged far behind the West, scientifically as well as economically and socially (Wang 2002). Recently, Xi Jinping, head of the Communist Party of China (CPC) and chairman of the People's Republic of China, has called for the "China Dream," which clearly resonates with the nationalistic notion of saving China through science and technology, a lasting dream of the Chinese people for more than a century. The revelation of the nationalistic lens for the understanding of current science education in mainland China is that receiving a science education is for Chinese students to help rejuvenate and strengthen China, a kind of collective conscientiousness that has motivated generations of Chinese teachers and students alike to pursue teaching and learning science (and technology).

Second, in line with the nationalistic lens, the political lens provides us with an understanding of science education in China that is, in a sense, characteristic of Chinese education in general, tracing back to the early twentieth century. The May Fourth Movement of 1919, a significant protest movement at this general time, started as a students' protest against Western and Japanese encroachment on Chinese sovereignty at the Versailles treaty negotiations. Leaders of this movement, including a few scientists, called for the introduction of "Mr. Democracy" and "Mr. Science" into China to reform its traditional pattern of culture and politics (Wang 2002). As two banners of the May Fourth Movement, many of the Chinese intellectuals adopted ideas of science (Mr. Science) and democracy

(Mr. Democracy) to inject into the minds of generations of Chinese teachers and students alike, a desire of modernizing China partly by teaching and learning science and technology.

In recent decades, such a political motivation among Chinese science educators and students has shown itself under the communist regime as well, in which "love of science," a slogan together with others, has been instilled into the minds of young children of many generations.

The third lens, the linguistic one, connects with science education through the revamping of the Chinese written language. One of the most influential philosophers, Hu Shi (1891–1962), first studied agriculture in Cornell University in 1910 and, having found his interest in philosophy a year later, transferred to Columbia University to study philosophy under John Dewey. While still there as a doctoral student, he initiated a movement for the vernacularization of the Chinese language as part of the New Culture Movement early in 1917 (Wang 2002). This has had tremendous influence on science education in China, as it has made it possible to translate Western scientific terms into the modern Chinese written language.

Writing about the influence of the New Culture Movement on physics education, for example, Jianjun Wang (1997), a Chinese American professor of science education now teaching at California State University, Bakersfield, comments that

> Had physics been explained in classical Chinese, students would have been burdened by the tedious language decoding requirement. In reality, classical Chinese was too outdated, and used only in written communications among a small group of Confucian intellectuals. The thorough reform of classical Chinese in the New Culture movement had made physics more accessible to the general public, and differentiated physicists from classic scholars in terms of the language style. (p. 335)

Taking as an example, the modern term for science is *kexue*, whereas before the 1910s "science" was translated into *gezhi*, a term borrowed from the ancient Chinese set phrase *gewu zhizhi*. As we use Chinese characters in written language rather than phonetic writing, learning and teaching science in Chinese language presents special difficulty for students and teachers alike. For instance, the concept of energy causes misunderstanding for Western students. However, similar misunderstandings happen with another concept "force" for Chinese students. The Chinese term "force" in daily life implies "energy" or "power" to some extent (Gao 1998).

The cultural lens, the fourth one, brings us to an insight into how science education in mainland China operates, within and outside schools. Although modern science seems to be perceived to be universal everywhere across the world, science education, both formal and informal, within China is taught and learned against the backdrop of Chinese culture in general, thus coloring the curriculum, pedagogy, and assessment of science education.

This is given great attention by Keith Levin (1987), a British comparative educationist, who, in studying science education after a study tour of China in 1984, alerts his readers of the need to "recognize the unique features of provision that make it unlike that in other countries. These include . . . the cultural traditions that shape pedagogy, the ideology of the state, and the rapidity with which changes have been taking place in the recent past" (pp. 420–421).

And finally, the fifth lens, the pedagogical one, which is interwoven with the cultural lens, enables us to see "special characteristics of Chinese science education" (Levin 1987, p. 440). As modern science came to China at the turn of the twentieth century, European pedagogy was introduced into China simultaneously to fit with the newly established teacher education system. At the very beginning of the twentieth century, the German educationist Herbart's pedagogy and especially Herbartianism were introduced and immediately became prevalent across China by way of translating Japanese pedagogical literature. This school of pedagogy was to set the tone for Chinese pedagogy and had huge impact on teaching, learning, curriculum, and assessment of almost all school subjects, including science.

However, the pedagogical lens is diverse and complex in the landscape of Chinese education in general and science education in particular.

After the May Fourth Movement which broke out as a national protest against Japanese aggression, China moved toward US educational sciences, especially following the academic tour of John Dewey in China from 1919 to 1921. For the next three decades until 1949 when the communists came to power in mainland China, it was the American educational sciences – including curriculum theory and the then newly emerging science education research – which came to dominate Chinese pedagogical discourses and exert considerable influence on educational practice.

In the middle of the twentieth century, there was a dramatic turnabout in the pedagogical discourses and theories as the CPC won victory against the nationalist government under Chiang Kai-shek. In the 1950s, the American educational sciences that had been pervasive in Chinese science education were critiqued and swept away as bourgeoisie. Instead, the Russian pedagogy was introduced into mainland China, which emphasized didactics and subject didactics. As a result, the Russian educationist I. A. Kairov (1893–1978) took place of John Dewey in communist China.

In the 1960s and 1970s, after the Sino-Soviet rift arose in 1960, the Russian influence was criticized too, and China began to explore its own way to establish a pedagogy based on Marxism and Maoism with Chinese characteristics. However, the decade-long Cultural Revolution (1966–1976), which caused a catastrophe for mainland China, rendered Chinese education into a wasteland. For example, the course content of physics, which has always been "king" among secondary science subjects in China, was reduced in most regions to only four components, the steam engine, the internal combustion engine, the electric motor, and the pump (Amidei 1980; cited in Wang 1997, p. 337).

The year 1978 saw the beginning of a new era for mainland China, initiated by the CPC's new policy of reform and opening up to the world under the leadership of Deng Xiaoping (1904–1997). Russian theories of pedagogy were again introduced into mainland China, together with North American educational science and European pedagogies. For the past three decades or so, both the Anglo-American "educational science curriculum" paradigm and the Continental-European "pedagogy-didactics" paradigm have converged in mainland China. This has resulted in a mishmash of pedagogical or educational discourses, which show themselves in many textbooks, with titles such as *Curriculum and Didactics of Physics*, *Curriculum and Didactics of Chemistry*, and *Curriculum and Didactics of Biology*, in use for the preparation of science teachers, both preservice and in-service, in Chinese universities and colleges. Without question, these textbooks and others relevant to science education provide science teachers with the main professional knowledge base which, in turn, comes to influence science education practice in mainland China.

Recent Reforms in Science Education

With the historical background described above in mind, I focus in this section on recent reforms in science education in mainland China. Since 1978, when China emerged from the disastrous Cultural Revolution (1966–1976) and entered a new era heralding reform and opening up, Chinese science education has experienced two main stages of reforms. These reforms have gained their driving forces both from the dramatic social change and transformation within China over the last 35 years and from learning from other countries, especially the USA. The first stage of reforms lasted from 1978 to the end of the twentieth century, during which science education regained its status in the Chinese schooling system and then started to reform, while the second stage began around the turn of the new millennium and continues today. It features a more conscious combination of internationalization and localization of science education in mainland China.

The First Stage: Reinstating and Reforming School Science (1978–1999)

The first few years of the late 1970s and the early 1980s saw the reinstating and reestablishing of the schooling that had been destroyed at every level during the disastrous Cultural Revolution. From the mid-1980s to 1999, precollege science education was fine-tuned and consolidated with new syllabuses for primary science and biology, chemistry, and physics for junior high schools (grades 7–9) and senior high schools (grades 10–12).

In primary schooling, “nature” as primary science became part of the curriculum again. Although the course had a similar nomenclature as it did before, its structure, content, and pedagogy changed considerably as it borrowed directly from the reforms of primary science education in the USA. Beginning from 1977, Brenda Lansdown (1904–1990), a Harvard professor of science education specializing in primary science, came to China for academic visits many times, involving herself deeply in the reforms of Chinese primary science. One of her major works – *Teaching Elementary Science: Through Investigation and Colloquium* (Lansdown et al. 1971) – was translated in 1984 into Chinese and printed many times and has since become a primer for primary science teachers, both preservice and in-service.

In terms of discipline structure, “nature” as primary science emphasized conceptual understanding of science rather than presenting just factual knowledge about nature, as it had done before in China. The curriculum content covered in the course and in student textbooks was systematic, coherent, and balanced in terms of physical science, life science, and earth and space science, i.e., the modernizing of primary science was in line with the US elementary science at that time.

Based on the reform experiences of the 1980s, “nature” as primary science in the 1990s became more consolidated as the new syllabus of 1992 for “nature” appeared and new textbooks in line with the syllabus for pupils and teacher guides were available.

In secondary schooling, science education in mainland China was heavily influenced by the USA as well. In 1979, Paul DeHart Hurd (1905–2001), then emeritus professor of science education at Stanford University, headed a group of American science educators that visited China, the first such visit since 1949. In response, Ye Liqun (1921–2000), then the head of People’s Education Press, led a group of ten Chinese science educators to visit the USA at the invitation of the US Ministry of Education in 1982 (Ye 1982). Both these visits opened the horizons on the part of Chinese science educators and effected a change in policy of science education in mainland China.

Another influence of American science education on mainland China came from taking advantage of the USA and other then industrialized countries’ science curriculum projects and materials developed in the 1960s and 1970s to update and modernize the curriculum of science disciplines for mainland China. In developing science programs for physics, chemistry, and biology and textbooks of each discipline for students and teacher guides for science teachers, Chinese science curriculum developers (scientists, didacticians of science disciplines, and experienced science teachers) in 1977 examined and adopted much from other countries, such as Japan, Western Europe, and most commonly the USA. They paid particular attention to the US curricula such as PSSC, CHEM Study, CBA, BSCS, and ESCP and took ideas from them for use in the unified textbooks they compiled for physics, chemistry, biology, and geography, respectively. In general, it appears that “teachers found many topics to be too theoretical for the majority of students to comprehend at the grade level for which the texts were originally written” (Hurd 1985).

As in primary schools, science curricula in secondary schools were revised and fine-tuned beginning in 1988 and completing in 1992, when new versions of physics, chemistry, and biology were proposed and new editions of textbooks for these science subjects compiled accordingly. This new wave of reform in secondary science focused on the following changes:

The Change of Science Education Goals. Due to the promulgation of the 9-year compulsory schooling law in 1986 by the central government, science education in junior high schools began to change its goals from a somewhat elite education model to a mass education model, so students’ interest in physics, chemistry, and biology were more emphasized in the syllabuses of each science discipline (Wei 2008).

One Syllabus Versus Various Textbooks. Formerly Chinese science education had been characterized by only one syllabus for each science subject at the secondary level and only one kind of unified textbooks for each science subject according to this syllabus which was produced by the official publishing house – the People's Education Press. In 1988 the Ministry of Education followed a new policy of "one syllabus vs. various textbooks" so that different types of high schools could choose them according to their needs and levels. Characteristic of these new textbooks were more up-to-date and refined scientific knowledge, more attention to development of competences in students, more emphasis on what was termed "double basics" (basic knowledge and basic skills), and strengthening the linkage between science education and the social and personal life of students. For instance, the idea of STS was introduced to serve the purpose of connecting (scientific) theory with practice (i.e., social and personal life), and STS contents were added into these textbooks (Wei 2008). In spite of these endeavors, however, the dichotomy of education for quality (*suzhi jiaoyu*) as a new policy of the Ministry of Education and examination-oriented education (*yingshi jiaoyu*) as a reality of the status quo of Chinese education was becoming more and more serious.

Integrated Science Programs on an Experimental Basis. One of the significant breakthroughs in science education reforms during this period came from Shanghai and Zhejiang province. In 1988, the Ministry of Education allowed both to experiment with their own curriculum and textbook production. In science education, both Shanghai and Zhejiang province started an integrated science program for grades 7–9 students in junior high schools. Despite strong opposition from conservative forces when the new curriculum was implemented in the 1990s, the integrated science curriculum in Zhejiang province made progress and converged into the new wave of national science education reforms in the new millennium.

The Second Stage: Science Education Reform Featured with a Combination of Internationalization and Localization (2000–2013)

Around the turn of the new millennium, a new wave of reform in schooling in mainland China began with an outlook toward the twenty-first century. To a large extent, this wave of reform in school science was more consistent with the mainstream of international science education reforms than previous reforms had been, just as the Chinese economy began to be more integrated into the world economy.

The new millennium saw the promulgation of the Ministry of Education's guiding plan titled "Framework for Basic (i.e., primary and secondary) Education Curriculum Reform" in 2001. It also witnessed the shift back of educational discourses from didactics to curriculum studies, such as "curriculum standards," which had been prevalent in the nationalist era of the 1930s–1940s. This now took place of "syllabuses" which had been in use since the 1950s when mainland China learned from the Soviet Union in many respects, education included. For the first time in Chinese educational history, primary science was to become a national curriculum that would replace "nature" and involve every child in science learning from grades 3 to 6.

In accord with the "framework" mentioned above, curriculum standards for primary science (grades 3–6), for junior high school science (grades 7–9), and for junior high school physics, chemistry, and biology were produced by committees of curriculum standards writing teams consisting of science educators and experienced teachers and published by the Ministry of Education in 2002. For senior high schools (grades 10–12), curriculum standards for physics, chemistry, and biology, respectively, were published by the Ministry of Education in 2003. In these science curriculum documents, such discourses as "scientific literacy," "inquiry-based teaching and learning of science," and "nature of science" were officially adopted, as by then the American science education reform documents of "Project 2061" (AAAS 1989) and the National Science Education Standards (NRC 1995) had all been translated into Chinese and became the most important reference materials for drafting Chinese science curriculum standards. Thus there was further internationalizing of science education in mainland China.

In contrast with the former syllabus for separate science disciplines, the new science curriculum standards have embedded the following basic ideas: science for all, promoting the development of every student, embodying the nature of science, emphasizing scientific inquiry, and reflecting the developments of contemporary science. To a large extent, these standards have integrated the science disciplines, since the conception of scientific literacy encompasses the overall purpose of science education throughout the science curriculum from primary schools to senior high schools. "Science literacy" is defined as consisting of four dimensions: (1) scientific inquiry (processes, methods, and competencies); (2) scientific knowledge and skills; (3) scientific attitudes, emotions, and values; and (4) the relationship of science, technology, and society (STS). To implement these new science curriculum standards, new textbooks have been compiled for primary science, integrated science textbooks for junior high, and physics, chemistry, and biology textbooks for both junior and senior high schools. Junior high schools are expected to choose either the integrated science textbooks or separate science disciplines for their students.

In order to promote the science education reform, one of the most important measures taken by the Ministry of Education is to train science teachers. In many universities and colleges, newly established centers of the curriculum reform have been founded, and science educators there plus temporarily employed experienced science advisors and teachers have become trainers. They offer short-term courses (normally 3 or 4 weeks) consisting of lectures given by scientists, didacticians of science disciplines, and expert science teachers, observing excellent science lessons given by expert teachers, participating in discussion and interaction with peers, etc.

The experimental exception to the national primary science education program is the "Learning by Doing" project. Originally imported from the French "La main a la pate" program in 2001, the "Learning by Doing" project was initiated by the China Association for Science and Technology (CAST) and the Ministry of Education jointly under the leadership of Prof. Wei Yu. It focuses on children in kindergartens and elementary schools having exploration study through hands-on activities. At present, nearly 20 regions across the country are involved in this project.

Summary

Science education in mainland China has experienced a fluctuation full of ups and downs over the past century. Originally imported from the West, it is clear that science education has become institutionalized in the Chinese schooling system and has tried to permeate the Chinese culture. Over the past three decades, science education in mainland China has been more and more integrated into the mainstream of international science education reforms, yet at the same time it has retained the Chinese way and thus is different from that of other countries in many ways.

Cross-References

- ▶ Cultural Influences on Science Education
- ▶ Didaktik
- ▶ Science Teacher Education in Mainland China

References

American Association for the Advancement of Science (1989) Project 2061: Science for all Americans. Washington, DC: AAAS.

Gao L (1998) Cultural context of school science teaching and learning in the People's Republic of China. Sci Educ 82(1):1–13

Hurd PH (1985) Precollege science education in the People's Republic of China. In MS Klein and FJ Rutherford (eds) Science education in global perspective. Washington DC: American Association for the Advancement of Science

Landsdown B, Blackwood PE, and Brandwein PF (1971) Teaching elementary science through investigation and colloquium. New York: Harcourt Brace Jovanovich, Inc

Levin KM (1987) Science education in China: transformation and change in the 1980s. Comp Educ Rev 31(3):419–441
National Research Council (1995) National science education standards. Washington, DC: NRC
Wang J (1997) A contextual examination of school physics in China. Sci Educ 81(3):333–354
Wang Z (2002) Saving China through science: the Science Society of China, scientific nationalism, and civil society in Republican China. Osiris 17(2):291–322
Wei B (2008) Science curriculum development in mainland China: retrospect and reflection for the past 30 years. J Chin Soc Educ 11:5–8 [in Chinese]
Ye L (1982) An investigation of science education in the USA. Curriculum, Teaching Material and Method, No. 4

Science Education in the Non-West

- ▶ Cultural Imperialism
- ▶ Cultural Influences on Science Education
- ▶ Indigenous Knowledge
- ▶ Japan, Science Education in
- ▶ Science Curriculum and Indigenous Knowledge
- ▶ Science Education in Iran
- ▶ Science Education in Mainland China
- ▶ Science Teacher Education in Mainland China
- ▶ Values and Indigenous Knowledge

Science Exhibits

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Science exhibits are displays that explore scientific objects, knowledge, process, and debate in an approachable, understandable manner. They deliver multiple levels of information and accommodate different learning styles.

Great science exhibits excite the emotions and stimulate the intellect while driving home an interesting, inspiring message about an aspect of science. After all, science exhibits are part of the informal learning experience, where emotional response usually paves the way for learning and engagement.

Science exhibits assume an endless variety of forms and styles, from dinosaur skeletons to gesture-controlled computers to dioramas to historical artifacts to interactive mechanical devices. The diversity of science exhibits is a reflection of the wide variety of institutions that create and house them.

History

Museums, in their modern sense as public institutions focusing on collections, research, and education, have been with us for over 500 years. The earliest museums focused on art and religious artifacts, and it was not until the eighteenth century, well into the Age of Enlightenment, when science emerged as a topic worthy of consideration for a museum.

The first science exhibits were collections of specimens gathered by nobility or other men of independent means. Naturalists, explorers, and traders were moving about the world with greater mobility and were able to gather impressive collections of specimens – common, rare, or just strange, the always popular “curiosities.”

One of the earliest public collections of specimens was put together in the late eighteenth century by Sir Ashton Lever, whose initial fascination with birds led to the creation of an impressive aviary. As his live birds inevitably passed on, many were stuffed and mounted, growing into a formidable collection. His holdings expanded as all manner of other specimens were brought to him. His collection outgrew his country home near Manchester, and he moved it to his London residence and, in a pioneering move, opened it as a museum for public visitation in 1774.

While Sir Ashton showed the way, the British Museum began to amass and display the world’s largest collection of natural specimens, leading to the creation of the separate Natural History Museum in South Kensington in 1881, creating a public treasury of the wonders of the natural world. In the early museums, exhibits were seen as basic teaching tools, unabashedly didactic and key to illustrating our rapidly growing understanding of the planet. Scientists combed the world for unusual expressions of the natural world, and thousands upon thousands of plant, animal, and mineral specimens were carefully collected and put on display, both for the growth of the science and for the edification of the public.

While stuffed animals and mounted insects made for a natural attraction, it was perhaps not quite so obvious that the stuff of science – the tools, technology, and engineering – also deserved pride of exhibition and scholarship.

Industrial society, in the form of tools, technology, and engineering, first appeared in museum exhibits in the Musée National des Techniques in Paris. A decree from the post-Revolutionary government in 1794 mandated the creation of a public depository for the rapidly expanding inventory of tools and inventions, plus the documentation that led to their creation. The physical facility opened in 1799.

At the dawn of the twentieth century, the newly founded Deutsches Museum in Munich took its exhibits in a different direction. Still didactic, still intent on teaching, it not only cataloged the past, it celebrated the contemporary. The Deutsches Museum was arguably the first institution to systematically collect and display the tools, instruments, and inventions of science and then add a layer of engagement through working models along with illustrations and diagrams explaining how things worked. It examined how technology affected the everyday life of Germans. The exhibits were more than a catalog of relics.

The idea of what a science exhibit could be evolved further in the 1930s with the opening of the Museum of Science and Industry in Chicago (1933) and the Palais de la Découverte (1937) in Paris. Both institutions developed exhibits that encouraged visitor involvement, whether it be walking through an enormous model of the human heart or actually conducting a simple experiment in a museum laboratory. These exhibits explored concepts like electricity and ecology and expressed science as a process, as opposed to just collections.

These important first steps were more fully realized in the 1960s and 1970s when exhibit designers began wholeheartedly to tackle the process of scientific investigation. In 1969, the Exploratorium in San Francisco and the Ontario Science Centre in Toronto opened their doors. The interactive science exhibit defined the entire personality of these institutions and captured the public imagination. The museum experience had been transformed from artifacts and specimens to the act of discovery itself. In these bold new institutions, the visitor became central to the act of learning. Artifacts and specimens were still present, but the most profound and popular exhibits were the ones in which the visitor took some control of the outcome and thus, in the well-designed examples, had a chance to behave and learn like a scientist.

There were levers to push, ropes to pull, balls to drop, and pendulums to swing. The choreography of action was intended to illustrate the laws and patterns in the world around us. After all, science simply states that the universe behaves according to a certain set of rules, and through experimentation and observation, we can figure out those rules. At the Ontario Science Centre and the Exploratorium, visitors were encouraged to test the rules for themselves. This gave rise to many famous and widely emulated exhibits – the Bernoulli Blower, the Van de Graaff generator, colored shadows, construction of catenary arches, and dozens of others.

Another great step forward in science exhibit content that gained momentum in the 1980s was the exploration of the social and cultural context of science, from AIDS to climate change to genetic modification to cultural bias in science. As science progresses, it not only increases our understanding and capabilities, it also often challenges our moral compass, and this is now a central part of the exhibit experience at many science museums around the world.

With the advent of ubiquitous digital connectivity, many exhibits are now being designed with internet elements as a core component. Prior to the 1990s, science centers and museums often featured exhibits that explained technology – the wonders of the computer and binary language and transistors. Those exhibits have largely disappeared, due in no small part to the rapid pace of technological change. Exhibits about technology show their age in short order.

As technology progresses, exhibits now feature technology as a central part of the experience. Multiuser touch screens, social media, mobile apps, and group interaction through smartphones are now a normal part of the exhibit landscape, but these advances will again soon seem quaint as new technology emerges and becomes even more an ordinary part of our everyday lives.

Signature Science Exhibits

Museums and science centers often have exhibits that are a core part of their personality and history. They develop and nurture these iconic exhibits to be part of their personality, part of their brand.

One of the best examples is the coal mine tour at the Museum of Science and Industry in Chicago. This exhibit is better referred to as an "experience," as it involves a descent into and tour through a simulated coal mine under the museum. The coal mine opened in 1933 and MSI calls it its first "interactive experience." It is a much-beloved part of the MSI experience. After 80 years in operation, and much retooling and upgrading, it remains a destination within the facility where parents who visited as children bring their children, passing on a sentimental connection to the museum from generation to generation. Similar sentiments surround the coal mine experience at the Deutsches Museum in Munich.

The Theater of Electricity at the Museum of Science in Boston is a core part of that museum's experience. It features massive electrostatic generators that were part of Robert Van de Graaff's teaching laboratory at the Massachusetts Institute of Technology (MIT). The artifacts are impressive in their own right, both technically and historically, but they are still operational and the museum uses them every day in a spectacular show on static electricity.

For decades, a Van de Graaff generator with a young girl's long hair billowing out above her head was the de facto brand image for the Ontario Science Centre in Toronto. The image wonderfully captured the essence of the interactive science center experience – exhibits that encouraged audience participation and which revealed spectacular and unusual results.

It is no accident that some of the largest museums in the world place dinosaur skeletons in positions of prominence. Since 1905, a massive diplodocus skeleton has dominated the Central Hall at the Natural History Museum in London. Iguanodon skeletons from a famous Belgian fossil pit have been the headline exhibit since 1882 at the Royal Belgian Institute of Natural Sciences in Brussels.

The Carnegie Science Center in Pittsburgh is home to a massive, highly detailed, and very much-treasured model railroad set in the hilly terrain of western Pennsylvania. It has been a work in progress at the museum since 1954. For 30 years, a live porcupine and beaver (actually, a succession of porcupines and beavers) have been unofficial mascots of Science North in Sudbury, Canada. The walk-through heart at the Franklin Institute in Philadelphia; the Paper Machine at Teknikens Hus in Luleå, Sweden; and the Gravitram at Questacon in Canberra (and other museums) are wonderful examples of exhibits that generations grew up with and that provide a "familiar face" for returning visitors.

Types of Exhibits

It is difficult to reduce the countless thousands of science exhibits to just a few categories, but there are some general broad groupings that help understand the character of an exhibit.

In reality, many exhibits will display elements of different categories, since there are no overarching rules for creating every exhibit. Each exhibit is an individual creation, and its success depends on how well its design deals with the intended message, visitor expectation, visitor behavior, and context.

Teaching Versus Learning

Didactic exhibits emphasize information and instruction. At its most basic level, a specimen, artifact, or phenomenon is presented with some combination of text, graphics, and audio to explain what visitors are viewing. This is very much a one-way teaching conversation from exhibit to visitor. It is perfectly appropriate for many exhibits, particularly when the item on exhibition has some profound historical or technical significance.

At the other end of a very broad continuum are the interactive exhibits that can be loosely categorized as "constructivist." Constructivism posits that learning comes from meanings created, or "constructed," by individuals building upon what they already know. In constructivism, learning is an active, social process. It may or may not come with instructions. It allows that learning takes time and that we build new knowledge through playing, testing, pondering, and thinking. Good interactive exhibits encourage this process by providing tools and context and put the acquisition of new knowledge, the learning, in the hands of the visitor.

Whether one is better than the other depends entirely upon the needs of the exhibit. In the end, the success of either approach, or anything in between, is only as good as its design and implementation.

During a visit to a science museum or science center anywhere around the world, a visitor can expect to encounter these types of exhibits:

Specimens

Specimens are the stock-in-trade of natural history museums – the bones, fossils, mounted animals, minerals, and other things collected from the natural world. They were also the very first science exhibits.

The earliest specimen-based science exhibits were heavily didactic, with an emphasis on teaching a specific piece of content, but usually with a sense of the dramatic. One of the earliest major science exhibitions was the Crystal Palace Dinosaurs, opened in 1854, a collection of life-sized dinosaur and mammal sculptures. It was a radical display in the mid-nineteenth century but then, as now, dinosaurs proved to be hugely popular with the public.

Some of the best-known and most popular exhibits around the world are based on outstanding collections of specimens. Museums off the beaten track, like the Royal Tyrrell Museum of Palaeontology in Drumheller, Alberta, or the Museum of the Rockies in Bozeman, Montana, attract huge audiences to see their magnificent displays of dinosaurs and other fossils.

Whether its fossils, minerals, gems, preserved animals and insects, bones, plants, or others, museums around the world give us a view into the wonder of the natural world through displays of their exhaustive collections.

But not all specimens are inanimate. At the Insectarium in Montreal, over 150,000 insects and arachnids are on display or in the collection. Live ants and bees are also on show in "vivariums."

Artifacts

Since the opening of the Musée National des Techniques in Paris at the very end of the eighteenth century, museums have been collecting and exhibiting the tools and technology that are the legacy of science.

One of the busiest museums in the world deals predominantly in artifacts of science and engineering – the Smithsonian National Air and Space Museum in Washington, D.C., where millions visit each year to see iconic airplanes and spacecraft, the real stuff of our technological history.

The Science Museum in London displays artifacts with profound historical significance, from the earliest surviving steam locomotive to a WWII Spitfire to early medical instruments.

Any museum is much more than just its artifacts, but through these collections of significant objects, we preserve, illuminate, and teach the history of science. And as an exhibit, the real artifact will always have much greater emotional impact on audiences than a replica.

Dioramas

Dioramas are the detailed recreation of a scene that incorporates three-dimensional objects surrounded by a carefully rendered background to provide context, perspective, and a sense of distance.

While dioramas are used in museums of all types, they are particularly associated with natural history museums as a technique for displaying posed animal specimens in portrayals of their natural environment. These displays can provide precise illustrations of animal behavior and habitat.

The earliest ecological dioramas are credited to Carl Akeley who created dioramas at several American museums. His exceptional craftsmanship is still on view at the American Museum of Natural History where the Akeley Hall contains what many consider to be the best dioramas ever created. His Mountain Gorilla diorama is perhaps the most famous.

Hands-On

The terms "hands-on" and "interactive" are often used interchangeably, but there are distinctions. Unfortunately, both terms suffer from vague, imprecise definitions and from overuse. They suggest an intent without providing any particular prescription for how to accomplish it.

Designers have tried to expand upon the term by coining variants like "hands-in" on "minds-on," encouraging greater consideration for how visitors manipulate and think about the challenges put before them.

One of the most ubiquitous interactive science exhibits, found in dozens of science centers around the world, is the Bernoulli Blower, first made popular at the Exploratorium in San Francisco. Frank Oppenheimer, the Exploratorium's founding director, used this exhibit as an example of how a well-designed interactive exhibit provided many different ways to interact. In this exhibit, a light beach ball or volleyball sits atop a stream of air directed upward through a nozzle. Visitors can tap on the ball and experiment with its movement in the stream of air. They may toss other objects into the stream or let their hair fly over their heads, or groups may toss the ball back and forth through the stream. Or some people direct the air up their shirts for the pleasant cooling sensation.

In this exhibit, there is no particular right or wrong. There are scientific principles that are illuminated and can be explored and toyed with, but at its core, the exhibit encourages experimentation and allows the visitor to take considerable control of the outcome. The exhibit is much less concerned with teaching a specific point than it is with encouraging visitors to observe and explore certain types of cause and effect.

Oppenheimer also felt that this may not be enough. With a little more thought and design, he figured this interactive exhibit could do an even better job of encouraging meaningful experimentation, and to that end, there are many variants of this exhibit in science centers around the world.

Science centers have been building "hands-on, interactive" exhibits since the late 1960s, and each one is still created from scratch, owing more to art than science, as each new exhibit sets its own rules for visitor involvement. As a result, in a visit to almost any science center, we see interactive exhibits that truly dazzle and others that fail to accomplish much at all.

Computer Based

Technology is allowing new techniques for engaging visitors in content. In the 1970s, 1980s, and 1990s, many science museums and centers developed exhibits about technology, introducing visitors to microprocessors and state-of-the-art tech innovation. Now that computer technology is so thoroughly embedded in our lives and advancing so rapidly, the focus has rightly changed to using technology to enhance exhibits and the visitor experience.

The museum world is embracing virtual exhibits – online catalogs, virtual reality, simulations, quizzes, multi-touch screens, smartphone apps, and countless others – and they are now an accepted, even expected, part of the museum landscape. Computers offer opportunities to simulate reality or construct scenarios that would not be possible in the real world. RFID chips allow visitors to track their progress through a museum. The Tech Museum of Innovation has built galleries of virtual exhibits in Second Life, doing things in the virtual world that are not possible in our physical space, extending the exhibit experience beyond the walls of the museum itself.

With the advent of more powerful processors, we are now seeing the first generation of "augmented reality" exhibits in which technology monitors physical interaction and provides real-time information or feedback. In an augmented reality exhibit, a museum visitor may manipulate an interactive exhibit, while a screen provides an animation that illustrates some element of how the physical interaction is controlling the environment. A smartphone or tablet pointed at an exhibit can produce a 3D avatar "host" who provides background information about the exhibit.

Outdoor Science Parks

Indoor environments come with restrictions. There is no wind and little or no natural light, and space is usually at a premium. Outdoor spaces provide the opportunity to create exhibits that involve the sun, wind, rain, and snow of the natural world.

They can involve water and sand and other materials that need to be tightly controlled indoors. And very often, the outdoors allows for very large exhibits that are impractical indoors, from large artifacts like airplanes to oversized levers that lift heavy objects to parabolic dishes that transmit whispered conversations across significant distances.

Unusual Media

There is no limit to the imagination found within science exhibits. The intersection of science, art, and other disciplines provides some of the most compelling artifacts of science.

A striking example is the Glass Flower gallery at the Harvard Museum of Natural History. It is a collection of about 850 plant and flower models, meticulously crafted from glass over five decades by a father-and-son team. The flowers were commissioned by a Harvard botanist who wanted high-quality models for instruction in botany. Exhibits like the glass flowers combine consummate artistic skill with scientific integrity.

Exhibitions of photography based on scientific images have become more common as imaging techniques have become more sophisticated. Images gleaned at the nanoscale or the cosmic scale come laden with scientific content and a profound aesthetic appeal.

Evaluation and Success in Exhibits

One of the most compelling questions about science exhibits is their effectiveness. Does an individual exhibit convey a meaningful message? Do exhibits increase an individual's understanding of science, and if so, how?

This is a difficult question to answer since museums and science centers are designed as places where individuals construct their own experience, choosing what to see, what to read, what to do, and how to explore the museum and its contents.

Researchers have tried to measure cognitive changes produced by exhibits and in a similar fashion to how we measure learning in schools. This has been problematic, since exhibits and the learning objectives for exhibits are different than those in the formal learning system. At school, specific content is taught and then retention and understanding by the student is measured, usually through exams. Exhibits don't work that way.

John Falk and Lynn Dierking have extensively studied how museum visitors interact with and learn from exhibits. Through their research, they have developed the "contextual model of learning" which proposes that how and what visitors learn in museums depend on their personal backgrounds, social interactions, and the physical environment. Decades after a visit, visitors often remember the physical environment in a museum more than individual exhibits. Understanding visitors' expectations and building appropriate physical contexts for exhibits are key to creating a powerful experience.

Research into how people learn gives strong clues about what sort of behaviors are indicative of learning. At Science North in Sudbury, Canada, Chantal Barriault identified a suite of behaviors that indicate different levels of cognitive engagement with exhibits. Evaluators observe visitors interacting with specific exhibits and track different types of behavior. Actions like acknowledging relevance and seeking or sharing additional information are strong indicators that learning is taking place, although the specific learning is often highly individualized for each visitor.

A related line of investigation has been intensively pursued at the Exploratorium in San Francisco. Their researchers measure exhibit effectiveness by assessing the quality of visitor interaction with the exhibit and the clarity of message the exhibit is conveying. They coined the term "Active Prolonged Engagement," or APE, to capture the key elements of a quality visitor experience with an exhibit. Visitors need to be *active*, doing things, in control of the outcome. Their exhibit experience should be *prolonged*, spending time with the exhibit to experiment and test. And they should be *engaged* and be stimulated intellectually and emotionally.

A framework like this provides an expansive, yet measurable, definition of what an exhibit should be. It provides a basis for carefully assessing an exhibit's effectiveness and is particularly useful for helping exhibit design team make an initial prototype better.

One of the biggest paradoxes in interactive exhibits is that it is possible that the activity, or the manipulation by visitors, can actually reinforce faulty impressions about how the world works. This is perhaps one of the biggest shortcomings of interactive science exhibit design, and it reinforces the need to prototype and evaluate exhibits, particularly interactive ones.

Creating Exhibits

The process of exhibit development varies widely between institutions and between projects, but there is a general road map that guides the process. Some museums have internal scientific and design teams to lead this process, but many rely on outside companies with specialized exhibit design, prototyping, and fabrication experience.

Museums and science centers usually create galleries or zones of themed exhibits. Exhibits supporting a similar theme are typically grouped together. This makes life simpler for the visitor, since they need cues as to how to behave (are these exhibits hands-on or not?) and what the overarching scientific and educational messages may be.

The first step is a conceptual plan that answers some key questions: Who is the audience? What are the educational/cultural/scientific messages? What will visitors do when they visit the exhibit? The conceptual plan lays the groundwork so that more detailed design has guidelines for development.

From the initial conceptual plan, ideas are refined to a schematic stage that describes what visitors will do with a specific exhibit, as well as the general dimensions and basic construction design.

Design development, up to and including final design, takes the exhibit to the level of detail necessary for fabrication. This is a challenging and complex process that requires creative, insightful solutions that are usually different for every individual exhibit.

During the schematic and design phases, prototypes are often constructed to try to answer very specific design challenges, especially for interactive exhibits. Prototypes provide important proof-of-concept feedback. They help designers understand how different materials work and how visitors will interpret instructions. It is unreasonable to expect that the first design of an interactive exhibit will work exactly the way it is expected to. Testing with prototypes, refinement of design, and listening to the exhibit users are all critical parts of creating good interactive exhibits.

In the 1990s, another important design element was introduced, that of “universal” or “accessible” design. This thoughtful approach to exhibit design provides equal access and enjoyment for everyone in the intended audience whether they are walking, wheeling, young, old, or physically disabled. Good universal design makes a better exhibit experience for everyone.

After the final design stage, specialized fabricators create detailed fabrication drawings and instructions so that they can build and install the exhibit according to the design team's vision.

Further evaluation of the installed exhibit helps an institution to refine and improve it so that visitors engage, explore, and learn.

Cross-References

- ▶ Interactive exhibits
- ▶ Museums
- ▶ Visitor Studies

References

Barriault C, Pearson D (2010) Assessing exhibits for learning in science centers: a practical tool. Visit Stud 13:90–106

Hipschman R, and Exploratorium staff (1987–1993) Exploratorium cookbook: a construction manual for Exploratorium exhibits, vols 1–3

Hein G (1998) Learning in the museum. Routledge, London

Humphrey T, Gutwill J, Exploratorium APE Team (2005) Fostering active prolonged engagement: the art of creating APE exhibits. Exploratorium, San Francisco

Kennedy J (1997) User friendly: hands-on exhibits that work. Association of Science-Technology Centers (ASTC), Washington, DC

Oppenheimer F (1976) Everyone is you... or me. Technol Rev 78(7). http://www.exploratorium.edu/frank/everyone/everyone.pdf

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Science Fairs

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Science fairs are events at which students display and discuss investigations they have conducted in areas of science, mathematics, engineering, computer science, and other areas (for instance, in some jurisdictions, psychology-oriented projects are included). Most often, science fairs are competitive events where projects are ranked and prize winners are chosen, although in some jurisdictions (such as the CREST (CREativity in Science and Technology) event in Australia), there are noncompetitive events. Science fairs have a long tradition in many jurisdictions around the world; at a recent international competition event (the Intel International Science and Engineering Fair), there were projects from 70 countries. In the United States, the genesis of science fairs was a science club movement that began in the 1920s, building to 600,000 participants within 20 years. These led to the first National Science Fair in 1950, and over the following decade science fairs gained considerable prominence as science itself gained a higher cultural value (related to technology such as atomic bombs ending WWII, the development of television and higher public awareness of science accomplishments). Currently, a country such as Canada, in which a national science fair started in 1962, has half a million students conducting science fair projects each year. Other large-scale competitions, such as the European Union Contest for Young Scientists, had an even later beginning (the progenitor of the EUCYS competition started in 1968).

Science fairs can be considered part of developing students' science literacy skills. Although subject to debate, the idea of science literacy can be broken into three essential parts: (i) science "facts," (ii) science investigation practices (skills related to investigating and creating "facts"), and (iii) science social practices (how facts come to be developed and accepted within the community of scientists, and outside influences on them such as the public and corporations). School science is often critiqued for developing understandings of "facts" but not the other two domains of science literacy. In fact, some argue that the directed ways in which school inquiry tasks are engaged are antithetical to the nature of authentic science. Science fairs may address this by helping students develop their understanding of the other two domains of science literacy through encouraging students to develop open-ended investigations within which they present and defend their work to others (judges, as well as other science fair participants and even the general public).

Much like formal science conferences, science fair projects are usually poster based with some artifacts present from the investigation, often including a detailed log and report book. The projects are set up for public viewing and each student has to give a short verbal presentation of their work (now sometimes supplemented by computer slideshow tools or video). Criteria for the formal judging are often available to the participants, although judges ask their own questions during and after the presentation by the presenter. Because of these poster and verbal presentations, science fair projects develop students' skills over and beyond those of just "science" but also in areas of critical thinking, problem solving, presentation skills, writing skills, argumentation skills, and others that are present in curricular documents for topics other than science.

Despite the positives that science fairs may offer, there have been many criticisms offered over the past decades. The judging process can be problematic since, in many circumstances, projects are judged by persons with an inadequate background for effectively evaluating the particular projects (this happens at all levels of science fairs). A high degree of corporate sponsorship, to the point that the commercial sponsors' name is in the name of the science fair itself, is considered by some to be problematic because of influences it has on attitudes about science-in-the-corporate interest. There is some suggestion that a bias in judging toward commercially viable science projects has led to students focusing on projects that are instrumentalist in purpose, designed to address specific problems that have commercial implications, rather than conducting science projects that are more in the realm of "pure science." The competition itself can lead to students feeling discouraged when their projects are not advanced and do not win mention or awards, and, consequently, they can develop negative attitudes about science. There have been calls for an alternative to the ranking/ribboning/prize-giving in science fairs for over 40 years. Discussions of science fairs in the media often focus on projects which are commercially oriented and, also, have a strong focus on the size of the prizes available (a recent junior high project in the United States won over $110,000 worth of prizes) and arguably help perpetuate traditional stereotypes about the practice of science. Often, students with greater access to resources (mentors, financial resources, etc.) are doing well in science fairs because they have a broader network of support than is available to most students, and thus science fairs are reinforcing and replicating socioeconomic status through these high prizes. Anecdotal evidence suggests that in many circumstances, parents have perhaps too active a role in the conduct of science fair projects, particularly in younger grades. The role of "science communities" also is considerably underdeveloped in science fairs, with projects often being conducted by solo participants with little interaction with peers over the student's engagement in carrying out the project, although, often in senior projects, there is participation with (quite senior) mentors. A final criticism about science fairs is that they often seem to strongly reinforce students using "the scientific method" (which has been roundly discredited as representing the actual practice of science in both the sociology and history of science literature) and, thus, may be misleading students about authentic practices of science.

More recently, online "virtual" science fair competitions have begun to have some prominence. The first were held in the late 1990s but these were mostly small scale. In 2011, the Google Science Fair began and, in its initial offering, there were 7,500 projects submitted to it – which were subsequently winnowed down to 60 semifinalists, from which three finalists (from each of three age categories) and a grand prize winner were determined.

Cross-References

- ▶ Inquiry, Learning through
- ▶ Scientific Literacy

Science Festivals

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"Science festivals" comprise a large, growing, and diverse community of science communication events. In recent years, the number of events has increased dramatically, and science festivals can be found almost all over the world, from San Diego to Novosibirsk, from Mauritius to Iceland, and from China to Brazil.

Basically, the term "science festival" covers a public event where science is presented to the public. Initially the "festival" part referred to the similarity with arts, film, or music festivals but with science as the main content. Consequently, many festivals were organized as projects or even as public or private companies with multiple stakeholders. Others were smaller, organized by universities, research organizations, or nonprofit organizations.

A study carried out in 2008–2009 (Bultitude et al. 2011) points to the growing popularity of science events. Festivals have been particularly common in Europe, but new events are introduced all over the world, not least in the United States.

Edinburgh in Scotland staged the first annual International Science Festival in 1989, to be followed by several others in Europe during the 1990s. In 2001, the European Science Events Association, Eusea (originally known as EUSCEA), was founded. Now, 10 years later, the association has approximately 100 institutional members in 36 countries.

During the almost 25 years that have passed since the first international science festivals, the profiles, purpose, and philosophy of the events have evolved, and today's festivals display a broad range of activities, places, and formats. From the start, "raising public awareness of science and technology" often was the most important reason to organize an event. In 2012, "public engagement" and "public participation" have become equally, if not more, significant profiles of an increasing number of festivals and events.

Science education and science festivals, representing formal and informal learning, seem to form a reciprocally beneficial relationship. Many science festivals have a specific program targeted directly at schools, thus becoming a valuable additional activity to everyday work in school and to national curricula (Lerch 2005).

The face-to-face meeting between scientists and the public is a signature characteristic of science festivals. Another is the festivals' way of organizing events at "unusual places," where science not normally is discussed. Shopping malls, railway stations, and other public places create a neutral place and an environment that allows interaction between scientists and members of the public on equal terms.

The value of the direct meeting has been recognized also by science museums and science centers. To an increasing degree, exhibitions in these places are complemented by activities such as lectures, experiments, and science cafés. Such activities may well fall under the umbrella of "science festivals"; indeed, several members of the European Science Events Association are science museums and science centers.

The opportunity for the public to interact directly with scientists seems to be appreciated, by both parties. In recent years, science festivals and science centers have also used their goodwill and actual arenas for policy-based activities, such as citizen conferences, student parliaments, and citizen exhibitions. The position of a center or a festival as a neutral platform with a broad range of stakeholders is advantageous, although the mandate from policy makers is essential for the engagement of the participating members of the public (ZIRN and W-i-D 2011).

From a research point of view, science festivals are still to be investigated in more detail. Evaluations are carried out to some extent but with different methods and in different languages, and the results are not always publicly available (Bultitude et al. 2011). The number of published articles is low, but presentations at conferences such as Ecsite (the European network for science museums and science centers), PCST (Public Communication of Science and Technology), and AAAS (American Association for the Advancement of Science) regarding festivals and festival activities seem to become more frequent. The body of work being built up is beginning to provide a compelling case for the value of science festivals.

Cross-References

- ▶ Café Scientifique
- ▶ Museums
- ▶ Public Communication of Science and Technology
- ▶ Public Engagement in Science
- ▶ Science Circus
- ▶ Science Museum Outreach

References

Bultitude K, McDonald D, Custead S (2011) The rise and rise of science festivals – an international review of organised events to celebrate science. Int J Sci Educ Part B 1(2):165–188

Lerch J (2005) Education. In: EUSCEA science communication events in Europe, EUSCEA, Vienna, pp 55–64

ZIRN and W-i-D (ZIRN/Universität Stuttgart and Wissenschaft-im-Dialog) (2011) Abschlussbericht Forschungsprojekt 'Wissenschaft debattieren! ZIRN & W-i-D

Science Fiction

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Keywords

Movies; Novels; Radio; Science in fiction; Science-themed fiction; Television; Theater

Introduction

Some entertainment media products, such as movies and television dramas, are created specifically to educate people about science. Many more are created primarily to entertain but nonetheless contain scientific information, scientist characters, or representations of other aspects of science. This science-themed fiction – including animated sitcoms, novels, radio serials, plays, comics, narrative-based computer games, and more – has the potential to teach people something about science. That potential may apply during leisure time when people consume the fiction purely for entertainment, in the classroom when a fiction text is incorporated into the curriculum, and in informal learning environments such as science shows or community theater when fictional elements are used to market the event or to engage audiences.

Often the first thing people think of when discussing fiction and science is the futuristic and fantastical genre of "science fiction," hence the title of this entry. But other genres of fiction – historical, romance, comedy, soap opera, satire, thriller, and the rest – are just as relevant (indeed, often more relevant) when they involve science-themed ideas, settings, plots, and characters. The term "science-themed fiction" is therefore a better way of capturing this range of possibilities.

Professionals concerned about the public image of science, including science teachers, have traditionally been wary of associating themselves with the science in fiction for several reasons. The scientific information in fiction is often incorrect, making science's defenders worry that it corrodes the public's scientific literacy. Scientists are often depicted in stereotypical ways in fiction (as nerds, as mad or evil, as middle-aged white men in lab coats, and so forth), which is frustrating for people trying to break down stereotypes if they feel fictional scientists are undermining their efforts. In addition, the dramatic or comedic or romantic or speculative elements of fiction can be seen as superfluous to learning and therefore as a distraction from the serious business of science.

This wariness has abated in recent years with science teachers and science communicators increasingly interested in using fiction to engage students' interest. Creative teaching methods and better understandings of the way people process fiction have demonstrated its potential utility for science education.

The two most pertinent questions about fiction for science educators are:

- Do people learn science from the fiction they watch or read for entertainment?
- If a fiction text contains incorrect scientific information, how can it be used effectively to teach science?

Learning Science from Entertainment Fiction

There is evidence that people sometimes learn scientific information from the fiction they consume for leisure. Most of the evidence comes from research into science-themed television programs, particularly medical dramas and soap operas containing health information, so this discussion will focus on that.

It is important to qualify what is meant by “learn scientific information.” The evidence we do have suggests that television audiences do not passively and uncritically absorb the science content presented onscreen. Rather, people are generally aware of television’s production contexts and conscious that dramas and comedies are created to entertain not primarily to educate. Viewers therefore make considered judgments about what information to believe or disregard, what to find out more about, and which programs to trust.

Some television dramas have successfully communicated important health information, educating viewers or prompting them to seek further information about the topic by raising their awareness of it. In some cases, this has changed viewers’ attitudes or behaviors, primarily when dramas have addressed personally relevant and taboo health topics such as HIV/AIDS, sexual health, and family planning. Salience is a key factor in learning, and learning science from fiction is a relatively short-term phenomenon unless the information is reinforced at the time through other fiction texts or sources such as newspapers, websites, and school lessons. Fiction is also most effective for health education when backed up by corresponding changes in society at large: for example, a program promoting condom use has little material impact if audience members cannot easily obtain condoms.

Television drama succeeds in teaching people health information for a number of reasons. Its spoken-word format reaches people who are illiterate or lack confidence in reading. The private location of television viewing enables health messages to be regularly delivered directly into people’s homes. The entertainment focus of television drama is its greatest strength. The emotional problems and everyday ethical dilemmas characters deal with are a major draw card for audiences, so packaging health information into such situations and dilemmas, particularly if dramatic consequences ensue, can teach audience members about health. Information presented through highly emotional scenarios tends to make the information more memorable. Drama’s nondidactic quality also appeals to audiences: they value the freedom to choose how to respond to any information presented, including the freedom to ignore it and just enjoy the show. Conversely, television audience members are frequently suspicious of documentaries because they feel documentary makers try to manipulate their beliefs by presenting their programs as “captured truth,” when in fact they are constructed entities like other television products.

Television drama is particularly successful at science education if viewers feel that its characters, settings, and stories reflect their social reality and if the scientific information presented is relevant to their lives and community. Locally produced programs that are created and set in the countries or communities where viewers live are more likely to resonate with viewers. In some countries and communities, other fiction media such as community theater or radio drama can work equally well or better than television drama, if they are an accepted mode of entertainment for their audiences.

More research on this topic is needed, examining fiction media and genres beyond television drama and science disciplines beyond health. Greater methodological rigor is required too, to avoid limitations that render a study’s conclusions questionable. For example, several researchers have used statistical correlations between people’s understanding of a scientific topic and their television viewing habits to conclude that television fiction teaches people science (including incorrect or marginal science), but did not establish that television fiction was actually the source of the scientific information.

Teaching Classroom Science Using Fiction

Using science-themed fiction to teach science in schools has become increasingly popular in the twenty-first century. Up until the 2000s, there was little published work on this topic, only a small number of journal papers and books, including the landmark *Fantastic Voyages* (Dubeck et al. 1994), which detailed many ways teachers could use movies to teach science. In the early 2000s, more educators began publishing their ideas for using fiction to teach science, in books, academic journals, and websites (see, e.g., Cavanaugh and Cavanaugh 2004; Raham 2004). The published literature now includes effective ideas and even entire curricula for teaching physics, biology, chemistry, health sciences and medicine, earth sciences, psychology, engineering, environmental sciences, forensic science, and mathematics. Some of these have been used effectively to recruit nonscience students to science classes. While there is minimal quantitative evidence of their pedagogical value, what has been reported has been positive in terms of student numbers, student attitudes, and improved marks. Popular fiction themes have also been used as marketing tools to draw visitors to informal learning facilities such as science centers, often in record numbers, and with anecdotal evidence that visitors then visit other exhibits, their interest in science successfully piqued.

Most educators using fiction to teach science turn the weakness of incorrect fictional science into a strength, by prompting students to identify the factual errors in a movie clip (or a short television program, excerpt from a novel, etc.). When teachers present movies and other fiction texts in classes without prompting students to critique the factual errors, students tend to learn the incorrect science as if it were correct, so teachers are advised to be vigilant. Asking students to explain why the science presented is incorrect engages their critical thinking capacities, requiring them to apply their knowledge. More advanced classes can strive for higher-order learning outcomes. For example, students can consider (and calculate) what conditions in the story would need to change for the science presented to be correct. Some teachers use this approach to integrate multiple topics from the science curriculum, requiring students to employ different kinds of calculations or different areas of knowledge when critiquing a fictional scientific phenomenon.

Science fiction movies are most frequently cited as the type of fiction used this way. They have a unique capacity to visualize outlandish concepts such as global disasters, genetic engineering and cloning, space travel, artificial intelligence, and nanotechnology, enabling teachers to draw attention to the limits of real-life scientific knowledge by way of comparison. However, other kinds of fiction can be used to equally good effect. Appropriate fiction texts for this purpose usually have three things in common: (1) a demonstration of an incorrect (sometimes correct) scientific concept, (2) entertainment value to engage students' interest, and (3) stated parameters within which to explore the scientific concept. The first is an obvious necessity for teaching, and the second makes fiction fun to use rather than an additional burden on students, who may already be struggling with the scientific subject matter. "Stated parameters" here mean the set of conditions in which the scientific phenomenon is demonstrated in the fiction text, such as the size of a fictional hurricane, the speed of a spacecraft, or the source of genetic material for a cloning experiment. The parameters give students a starting point from which to calculate or evaluate the plausibility of the fictional scenario, much as worked examples in textbooks do.

Fiction has also been used to teach more socially oriented elements of science, such as the ethics of controversial science and technology or role-modeling good scientist behavior. Since ethics and other science, technology and society (STS) topics necessitate student engagement with human contexts – including understanding the feelings, values, cultural influences, power dynamics, political views, economic needs, and more that arise when people collide with science and technology – the ideal pedagogical tool will have those elements of human context as its core material. Science-themed fiction is one of the few resources available to teachers that situates science within a human context in this way. Its similarity to real life grants students some plausible stated parameters to work with (in this case human parameters), but its distance from real life enables classroom debates to maintain a hypothetical status unobstructed by the contingencies of real-world case studies.

An innovative approach to using fiction in the science classroom, which deserves further development, is to ask students to write a story about a scientist (Reis and Galvão 2007). Through this task, teachers can explore students' preconceptions about what science is, who scientists are, what scientific work is like, and where science sits within students' lives or the world as they see it. In line with work on redressing scientific misconceptions, this is a fruitful method of bringing to the fore ideas students have that they may not be fully conscious of thinking. The stories may then provide a focal point for discussion and for educating students about what science is really like.

Cross-References

- ▶ Alternative Conceptions/Frameworks/Misconceptions
- ▶ Broadcast Media
- ▶ Health Education and Science Education
- ▶ Imagination and Learning Science
- ▶ Interactive Science Centers
- ▶ Learning Science in Informal Contexts
- ▶ Public Engagement in Science
- ▶ Science and Society in Teacher Education
- ▶ Science Theater/Drama

References

Cavanaugh TW, Cavanaugh C (2004) Teach science with science fiction films: a guide for teachers and library media specialists. Linworth Publishing, Worthington

Dubeck LW, Moshier SE, Boss JE (1994) Fantastic voyages: learning science through science fiction films. AIP Press, Woodbury

Raham G (2004) Teaching science fact with science fiction. Teacher Ideas Press, Portsmouth

Reis P, Galvão C (2007) Reflecting on scientists' activity based on science fiction stories written by secondary students. Int J Sci Educ 29:1245–1260

Science for All

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"Science for All" is an aspirational phrase that has repeatedly embodied the hope that all members of society, and in the particular case of education, all students, will be able to share in some way in the richness of discovery, explanation, invention, and application that characterizes science as a great human endeavor. Probably first use of the phrase was as the title of a lecture in 1847 by James Wilkinson, a surgeon, in London. In his strong plea for sharing the benefits of science with society at large, he identified several points of hindrance that have been, and are still, evident in the many attempts that have followed to implement this aspiration through the education system.

One point was that the end for which scientific knowledge was sought and recorded by the learned and the end for which it is required by the multitude are not the same, but different. Others were that many scientists consider scientific knowledge as intellectual property to be transmitted unimpaired from generation to generation rather than rewriting it for public use and that they are more concerned to be judged by their peers than with relating the potential of their findings for the life of society. Recognizing and dealing with these insights about the nature of the gap between science and society have, alas, too often been forgotten or overlooked in the many twists and starts that science for the masses has taken in the intervening 150+ years. Wilkinson's points have repeatedly occurence in the numerous attempts in that time to enable Science for All to be the priority goal of school science.

In the years following Wilkinson's lecture, much more was done at the public level than at the school level to provide education in science to the masses. In the nineteenth century, the Mechanics Institutes in Britain and their counterparts elsewhere made lectures on science cheaply available to the public, and these were supplemented by a variety of science-based magazines. In the first half of the twentieth century, a spate of small books on aspects of science appeared, written by leading scientists enthusiastic to share their knowledge. The best-selling book, *Science for the Citizen* by Lancelot Hogben, met and enhanced an obvious public interest that nowadays is further stimulated and met by the natural history and science programs of the BBC and National Geographic.

With respect to school science, there was enthusiasm in England in the 1930s for the teaching of general science, as an alternative or precursor to the teaching of the separate science disciplines, and similar moves occurred in other countries. In each case these alternatives, in due course, languished when it became clear that the new approach was being associated with less academically oriented students and hence carrying less status than the traditional science subjects. As part of the 1960s era of new science curriculum projects, there was also a brief flourishing in pilot form of a Unified Science Education course in the USA and of the Schools Council Integrated Science Project (SCISP) in England that minimized the differences between the disciplinary sciences in favor of more general big scientific ideas, but these failed to become in any way mainstream.

In continental Europe the "didaktik" tradition in education, as compared with the Anglo-American tradition, has more clearly differentiated Wilkinson's point about the scientific knowledge needed by scientists being different from the scientific knowledge needed by citizens as a whole. However, the specialist teaching of the science disciplines in Europe has militated against their knowledge being brought together in a way that addresses the multidisciplinary realities of science and technology in society.

Science for All next became a widely used slogan in the 1980s reflecting a widespread aspiration for a reform of school science education that would widen the contribution it could make to all students and not just to the minority of future science-based professionals, the primary beneficiaries of the 1960s reforms. The slogan was launched in a number of important national reports, Science for All Americans, Science for All Canadians, and in a UNESCO report, Science for All, generated in its Asia/Pacific Region. Each of these set out a broad brush case for this widening of school science's target leading to a new set of aims for school science. The Canadian set was the most fulsome with science education being a preparation for the world of work and for moral development as well as the more customary aims of meeting the needs of the science career-oriented students and of the whole student body's participation in science and technology situations. With the dawn of the twenty-first century, both the world of work (the demand for generic competences) and the ethical challenges (such as global warming, world health, the need for water, etc.) have added new complexities to the teaching and learning of science.

As in the earlier attempts to achieve Science for All, these intentions in the 1980s have also proved difficult to translate into an acceptable and operational curriculum for school science, although a movement to use the trio of the science-technology-society as a frame for school science showed promise for a few years in several countries. It seems as long as there is the expectation that school science will act as a preparation for, and a selection of the small proportion of students who aspire to high-status career courses like medicine and engineering, it will remain difficult to develop a similarly highly regarded and differently designed course of more general science study.

By the 1990s "scientific literacy" had replaced "Science for All" as a slogan, in part to give it a more operational tone and in part to ally science education with the preeminent position, particularly in relation to primary or elementary education, that number literacy and language literacy have always had. In 2007, Douglas Roberts used the new slogan to clarify the issue to which Wilkinson had pointed by defining two visions of scientific literacy: one turned inwards to the sciences themselves and one turned outwards to those real-world situations involving science and technology that we all, as citizens, increasingly encounter. The first vision leads to a curriculum in which what is to be learned is listed in terms of a logical development of separate science disciplines, albeit encouraging interaction of these in interdisciplinary phenomena. The second vision leads to a curriculum that is thematic in structure drawing on whatever disciplinary knowledge is appropriate and building up big scientific ideas and principles.

The task of balancing the science curriculum in terms of these two visions is now evident in recent curriculum documents around the world. The Twenty-First-Century Science Project in England is one example, as is the addition in Australia of “Science as Human Endeavour” as a new strand of science content. The OECD’S PISA project for assessing science learning has also encouraged these endeavours.

Cross-References

- ► Curriculum Movements in Science Education
- ► Scientific Literacy

Science for Citizenship

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Contemporary science curricula in many countries emphasize the importance of educating a scientifically literate citizen, who is able to participate in debates and decision-making related to the issues societies have to face in which science and technology are involved (e.g., energy resources and consumption, water, food and agriculture, human health, global warming, nanotechnology, information). Better informed democratic participation is the aim of science education. This can be related on one hand to a public distrust of scientific expertise in the context of recent health and environment crises related to science and technology (for instance, mad cow disease, the Chernobyl and Fukushima nuclear accidents, genetically modified food, the impact of genomics on medicine) and on the other hand to a problem in several countries of a decrease in the number of university students in science (particularly in physics). Democratic participation as an aim of science education may serve as an argument for the presence of science education in secondary education, or alternatively it may orient a deep change of science education curricula to meet the needs of youth in today’s society. While many agree that an important aim of science education is to enable democratic participation, science education for citizenship is also a formidable task (Levinson 2010).

Legitimate concerns of citizens may be interpreted by some philosophers and sociologists as a symptom of a problematic increasing gap between science and society. From such a perspective, science and society are considered as separate spheres that may interact with each other. Some scientists fear that society’s support for science through public funding of research may decrease and, hence, call for urgent action to improve public understanding of science. Science education is considered in this context to have a particularly important role. Science for citizenship is, from this perspective, considered to be a possible way to “reconcile” pupils (as current and future citizens) with science and technology, leading to an argument that scientists should engage in actions oriented towards schools. Depending on the nature of the pedagogical activities, science for citizenship may appear to be a slogan to popularize science or communicate the benefits of science and technology. This slogan aims at making science teaching more attractive while maintaining a tradition of the teaching of science content (and marginalizing knowledge of the nature of science or of history and sociology of science). Other scholars have argued, however, from the critical study of international surveys like PISA and other recent reform efforts, that “science for citizenship” is a renewed expression of an old hegemonic project to impose the values of Western societies upon the world (Carter 2008).

A more commonly held view is that “science for citizenship” invites science educators to engage in a deep reformulation of a school science curriculum that no longer meets the needs, interests, and aspirations of young citizens. If current social and environmental problems are to be solved, they argue, we need a generation of scientifically and politically literate citizens in the context of economic globalization, increasing production, and unlimited expansion that threatens the freedom of individuals, the spiritual well-being of particular societies, and the very future of the planet. To achieve such a goal, some argue that the science curriculum should be oriented towards sociopolitical action (Hodson 2003). From this perspective, science for citizenship implies the democratic participation of citizens in scientific and technological affairs (from public debates, to decision-making on socio-scientific issues, to science and technology research policy).

Within these various perspectives on science for citizenship, different perspectives on the “citizen” are apparent. A citizen may be reduced to a consumer of goods, if scientific literacy is developed in order to equip pupils to become sufficiently aware of science and technology for decision-making about purchases. On the other hand, a citizen may be considered a professional if science for citizenship is focused on work preparation. Or the focus may be on the “average citizen” who has to understand and cope with everyday phenomena and participate in political decision-making on issues that require an understanding of science and technology.

This is also an aim of those who advocate science education approaches such as science-technology-society (STS), science-technology-society-environment (STSE), and the discussion of socio-scientific issues (SSI). It is also closely linked to the vision of scientific literacy which Roberts (2007) names Vision 2.

Cross-References

- ▶ Ecojustice Pedagogy
- ▶ Environmental Education
- ▶ Interests in Science
- ▶ Socioscientific Issues

References

Carter L (2008) Sociocultural influences on science education: innovation for contemporary times. Sci Educ 92:165–181

Hodson D (2003) Time for action: science education for an alternative future. Int J Sci Educ 25:645–670

Levinson R (2010) Science education and democratic participation: an uneasy congruence? Stud Sci Educ 46:69–119

Roberts D (2007) Scientific literacy/science literacy. In: Abell S, Lederman N (eds) Handbook of research on science education. Lawrence Erlbaum, Mahwah, pp 729–780

Science for Girls

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The underrepresentation of women in science first became a focus in the late 1970s and early 1980s when two bodies of literature – feminist theory and the history of women in science – converged. What emerged was the realization that women in fields of science were not being adequately recognized and women in the process of choosing fields of study were not pursuing science careers in ways that were consistent with their numbers or level of achievement.

Inequitable opportunities for girls to participate in science have been documented in schools, in programs outside of school, and even in the differential treatment offered by a parent or guardian at home. Enhanced awareness and interest in addressing the underrepresentation of girls in science led to a variety of programmatic efforts. While examples of gender inequity and stereotyping continue today, apparent in school texts, children’s books and movies, classroom experiences, exposure to science toys, and other science-related experiences, there has also been great progress.

Data gathered by a variety of agencies (American Association of University Women 2010; National Science Foundation 2011; Department of Education 2012; National Science Board 2012) now focuses not just on science but on **s**cience, **t**echnology, **e**ngineering, and **m**athematics – often referred to as STEM. This statistical evidence suggests that there is greater equity in school and test performance, as well as class participation in the STEM fields. But even though girls and boys do not differ significantly in math or science performance, boys' confidence and interest in science majors and careers exceeds girls'. Women outnumber men in biology, psychology, and social sciences but are greatly underrepresented in engineering, computer sciences, and physical sciences. In these male-dominated areas, women earn less than 20 % of the bachelor's degrees awarded each year. This underrepresentation of females and minority groups in particular STEM fields remains a troubling issue.

Girls' Learning Preferences

Getting turned-off or pulled away from STEM careers, especially in the fields of physics and engineering, appears to be the result of an intricate web of experiences at home and at school, societal messages through media, toys, games, books, and expectations about what science is and who does it. A growing body of research on identity development posits that an important ingredient to a girl's ultimate engagement in STEM fields is her development of a sense of herself as someone who "does science." Important to note is that the percentages of women and men who are in STEM fields worldwide vary greatly, providing additional evidence that women's pursuit of science is not a capacity issue, but a cultural and/or environmental one.

A powerful strategy for encouraging girls in pursuing science as a hobby, interest, or career has been the development of girl-focused science programs outside of school. Informal settings provide unique opportunities to engage with and connect with science in an inquiry-based manner without the academic requirements of memorization and standardized testing. A strength of informal environments is support for science learning in ways that utilize learning strategies found most effective for girls. These include opportunities to investigate and learn in safe, nurturing environments, offering noncompetitive, nonjudgmental surroundings that often include opportunities for cooperative learning and exploration and activities that are personally relevant, process oriented, and socially impactful. While these experiences may be effective for all children, research suggests that it is these approaches that are particularly critical in engaging girls.

Informal Programs That Support Girls' Science Learning

There have been several hundred girl-focused programs supported by various federal agencies and foundations over the last decades. These programs focus not only on content and inspiring girls to pursue careers in science but also on developing confidence, positive attitudes about science, and a broader understanding of the ways in which one might engage in science learning and practice.

Informal science programs vary widely in their offerings and intended outcomes. Most efforts offer access to STEM learning through a variety of access points or strategies that may include:

- Female scientist role models
- Field trips
- Hands-on activities
- Project-based/inquiry-based opportunities
- Teaching others
- Working within science strong institutions, companies, or programs
- Career awareness and development activities
- Exposure to unique experiences

Activities can be extremely diverse, ranging from programming computers, or building and shooting off rockets, to digging for fossils, conducting a water study, or growing fruit flies.

Settings vary from museums and zoos to after-school programs, outdoor classrooms, field-based sites, community-based organizations (CBOs), and clubs. Some of these programs last for an afternoon; others run intensively for years. While informal STEM programs may offer exposure to skills and practices, all vary not only in structure and intensity but also in their connection to a larger community of people committed to science and/or girls. The result is outcomes beyond science learning that include improved self-esteem, self-efficacy, and leadership skills.

Recommendations for Encouraging Girls in Science

While research about women's long-term participation in science resulting from participation in informal science programs is modest, there is evidence that informal STEM experiences can be beneficial in supporting and building capabilities, experiences, and confidence in science. Some recommendations to support girls in science include the following (Halpern et al. 2007; Afterschool Alliance 2011; McCreedy and Dierking 2013):

1. Integrating girl-friendly strategies
2. Providing experiences that enhance girls' beliefs about their abilities to participate in and contribute to science
3. Exposing girls to science careers and female role models in ways that illustrate their importance and value so that a career in science is seen as significant, and just as valuable as others, and a place where they could belong
4. Appreciating the benefit of providing multiple access points to science learning and continued support in pursuing and extending stem interests once engaged
5. Offering rich and diverse stem experiences and unique opportunities that expand girls' understanding about what counts as science
6. Providing opportunities that empower girls to take charge, teach others, and learn authentic science skills and practices
7. Integrating math into stem programs in authentic ways that do not position it as a gatekeeper or barrier to all pathways to science
8. Viewing stem as a vehicle for growth, appreciating that stem experiences and youth development can and do go together

Ideally, informal STEM learning experiences for girls, along with experiences they have at home, school, university, and the work place, build upon one another, as well as connect to and reinforce the countless other experiences in a girl's lifetime.

Cross-References

- ▶ Gender
- ▶ Gender-Inclusive Practices
- ▶ Learning Science in Informal Contexts

References

Afterschool Alliance (2011) STEM learning in afterschool: an analysis of impact and outcomes. Afterschool Alliance, Washington, DC

American Association of University Women (2010) Why so few? Women in science, technology, engineering, and mathematics. American Association of University Women, Washington, DC

Halpern D, Aronson J, Reimer N, Simpkins S, Star J, Wentzel K (2007) Encouraging girls in math and science (NCER 2007–2003). National Center for Education Research, Institute of Education Sciences, U.S. Department of Education, Washington, DC. http://ncer.ed.gov

McCreedy D, Dierking LD (2013) Cascading influences: long-term impacts of informal STEM experiences for girls. The Franklin Institute, Philadelphia. http://www.fi.edu/girls/cascading-influences.pdf

National Science Foundation (2011) Science and engineering degrees: 1966–2008. NSF 11-316, Arlington. http://www.nsf.gov/statistics/nsf11316/

Science in Fiction

▶ Science Fiction

Science Inquiry

▶ Internet Resources: Designing and Critiquing Materials for Scientific Inquiry

Science Kits

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Science kits have grown in popularity in recent years and have been increasingly used in elementary and middle school science instruction. Science kits typically include materials for students to use to do an investigation and instructions for teachers on how to use the kit as well as background information. Kits also may include supplementary materials such as related literature, other investigations, and suggested assessment items. Generally kits are created to be all-inclusive and are designed to be used with minimal preparation time. Most kits focus on a single science topic such as magnets or rocks.

Science Kits and the Curriculum

Early science kits were designed for students to use as take-home experiments that could be done as an extension of classroom instruction or as a family science activity. In the 1960s kits emerged as a tool to help teachers implement inquiry by providing materials and instructions. These kits were followed by longer-term kit programs that were designed to promote the development of inquiry skills by engaging students in experimentation. Science kits have emerged as tools for schools, distance education programs, and home use.

Today extensive kit-based science programs are developed and distributed by school systems, textbook publishers, and science supply companies. Science kits are also often available from institutions such as science centers and museums and are mostly designed for use in schools. These kit programs include a variety of topics and include kits for multiple grade levels. Most of the science kit programs have focused on the elementary grades, but there are now science kits developed specifically for middle and high school science programs.

In some school systems, kits are designed to be used as the science curriculum, but in many cases, kits are used as either a supplement to the curriculum or stand-alone units that can be implemented as needed. The inclusion of materials and directions for investigations is common to nearly every type of science kit. It is common in school systems that use kit-based science programs for kits to be refurbished centrally, thus removing teachers from the burden of locating, storing, or inventorying materials.

Challenges to Using Kits

Although there are distinct advantages for teachers to use kits (materials are provided and there is no need to purchase, store, or inventory materials), these very advantages for individual teachers provide significant challenges for school systems that must purchase kits, resupply the materials, and provide a distribution system for delivery and pickup. The effort for providing and maintaining materials shifts from the level of the teacher (and school) to a central authority. Often this change in responsibility is accompanied by a shift in funding for science from the school to a central school system program.

Kit Effectiveness

In general, research on science kits has shown that kits have a positive influence on teachers' and students' attitudes about science instruction and can promote the use of inquiry in science classes. Kit use has been shown to impact student achievement. Dickerson et al. (2006) examined teachers' use of kits with 2,299 elementary school students in three grades. Schools that used a kit program were compared to schools that did not use kits. Student scores on achievement tests were compared, and for 15 matched school samples, five of the schools that used a kit-based science program had statistically higher scores, and only one of the traditional science program schools had higher achievement.

A study by Jones et al. (2012) of 503 elementary teachers found that teachers' instructional strategies, classroom practices, and assessment varied according to how frequently teachers used science kits. Jones et al. reported that teachers who used kits most often were more likely to have their students design experiments and collect and analyze data. In addition, the teachers who used kits often were more likely to use small-group learning and alternative forms of assessment such as portfolios and notebooks. Teachers who used kits less often tended to report more traditional types of instruction, including having students practice for standardized tests.

Like other forms of curricular innovation, kits are most effective when they are aligned with teachers' existing beliefs and practices. Rennie et al. (2010) maintain that teachers need deep content and pedagogical knowledge to effectively implement inquiry with kits. For school systems that move to using kit-based curricular programs, these differences in teachers' experiences, competencies, and beliefs must be taken into account when making this kind of systemic change. But even with the challenges of implementing a science kit-based curriculum, schools often report improvement in teachers' confidence in teaching science as well as an increase in the use of inquiry.

Cross-References

- ▶ Science Community Outreach
- ▶ Science Museum Outreach

References

Dickerson D, Clark M, Dawkins K, Horne C (2006) Using kits to construct content understandings in elementary schools. J Element Educ 18(1):43–56

Jones MG, Robertson L, Gardner GE, Dotger S, Blanchard M (2012) Differential use of elementary science kits: one size does not fit all. Int J Sci Educ 34(5):2371–2391

Rennie LJ, Howitt C, Evans R, Mayne F (2010) Do-it-yourself astronomy: getting the best out of science kits. Teach Sci 56(4):13–17

Science Museum Outreach

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As long ago as 2001, the director of the Science Museum of Virginia, Richmond, USA, in an article for *ASTC Dimensions*, described his institution as a "community powerhouse." He rightly pointed out that science museums and science centers have many roles to play in serving their communities, many of which can only be fulfilled through "outreach."

Outreach is capable of many definitions, but one which applies well here is "any systematic effort to provide unsolicited and predefined help to groups or individuals deemed to need it." This is not a new form of education: as early as 1891, the "science demonstrator" to the Birmingham School Board in England had adopted an outreach program which circulated science teaching equipment and samples to schools in a handcart. The motivation, then as now, was to provide resources where they were most needed – economically and efficiently and in a timely manner. Science museums and science centers embraced outreach from their early years. Museum loans of natural history specimens to schools were common during the twentieth century, and early-established science centers like the Ontario Science Centre were taking programs to remote areas (and, in the specific case of OSC, education programs for students and teachers in the schools for Canadian Forces based in Germany).

In the succeeding years, the reasons for conducting science museum outreach have become more subtle. A process which may have begun as a profile-building exercise or for meeting a resource deficit has evolved into a developed sense of responsibility for promoting community engagement – in ways that are

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"This article was written in 2012."

similarly practiced by orchestras, football teams, opera houses, and theater companies. Such engagement may be socially motivated (e.g., in using outreach programs to promote social cohesion) or driven by a wish to take science directly to the public. An important element in science museum outreach activity is engagement with the formal education system through visits to primary and, less frequently, to secondary high schools.

Examples from around the world are now chosen to illustrate the various methods and motivations for delivering outreach programs from science museums and science centers. The broadcast media and online activity are excluded from this account, as they are treated separately elsewhere.

The Shell Questacon Science Circus claims to be "recognised as the most extensive and longest running touring science centre outreach program in the world." Using a large vehicle and a team of presenters, it offers school shows, professional development for teachers, a traveling science center for the community, and extension activities for senior high school students. This is a model which has been adopted worldwide and indeed was being used, e.g., by the Ontario Science Centre, as early as 1971. The Australian science circus has another purpose; however, it is a core component of the training of future science communication professionals who are following a Master's program at the Australian National University, Canberra. It has also undertaken an "ambassadorial" visit to China.

Science on the move, using vehicles ranging in size from caravans to tractor-hauled multi-wheel trailers can now be found on every continent. Heureka, the Finnish science center, has even offered science shows on cruise ships in the Baltic. PROMUSIT is the traveling museum program from MCT-PUCRS, the interactive Museum of Science and Technology run by the Catholic University of Rio Grande do Sul, Brazil. In operation since 2001, it carries 70 exhibits, a collection of interactive kits, and provides an air-conditioned auditorium within the vehicle. The DESTINY program in North Carolina, USA, originating in 2000, has two 24-place mobile laboratories operated by the Morehead Planetarium and Science Center. The MysteriX science truck from the Technopolis science center in Mechelen, Belgium, has been touring Flanders since 1998. It converts to a mobile laboratory with a themed program in which students have to solve a series of problems within a fixed time to prevent the world from being extinguished by "a mystery virus." In Mauritius, the Rajiv Gandhi Science Centre's "Caravane de la Science" provides interactive science demonstrations, exhibits, and film shows "to explain science concepts. . .and encourage critical thinking," while their science bus contains 24 interactive exhibits on the theme "We are one" – regardless of color, caste, or race, our bodily organs perform the same functions.

This last example hints at the importance throughout the world of using science outreach to support social cohesion and well-being. Science centers and other informal learning environments are increasingly concerning themselves with socio-scientific issues, sometimes with the aim of influencing attitudes and behavior. A recent study investigated the effects of an HIV-AIDS science theater presentation on the behavioral intentions of 697 South African students, a population facing extreme HIV risk.

Ecsite's PLACES project moves the sociopolitical goal to a policy-making level. Its aim is "to enhance the three-way conversation between science, policy makers, and society", and many European science centers are involved in its "Science Cities Workshops."

Family workshops conducted by London's Science Museum in three different prisons have helped in the difficult process of consolidating relationships between prisoners and their families. Thinktank in Birmingham, UK, has undertaken a series of programs with elderly residents in care homes, in some cases supporting those with dementia as well as age-related physical disability.

Such programs have been described as "citizen science," ultimately enhancing democracy as well as social and economic development, along with fulfillment for the individual.

Transport options must be appropriate to circumstance, and the Manthan Science Center, India, used a camel-drawn cart laden with posters and solar viewers for its participation in the "100 h of Astronomy" program of International Astronomy Year 2009. Elsewhere in the same country, it was possible in 2012 to visit the Science Express Train, with its exhibition on biodiversity and conservation, the "joy of science" hands-on lab, and a teacher-training facility. In Bogotá, Colombia, the Maloka science center has a Cycle Science program in which bicycles equipped with hands-on science activities tour the city streets on Sundays. It also reaches out to municipalities without roads or land access, using boats fitted out as floating classrooms with satellite internet connection.

The principle of the "circus comes to town" is widely adopted by science centers, with many examples of touring programs that settle for a day or two in places where families are generally to be found: shopping malls (an example from 2001 was Science on the Mall: large-scale interactive exhibits from SciTech, Aurora, Illinois), parks (e.g., the Science Picnics in Warsaw – "Europe's largest outdoor science popularization event" organized jointly by the Copernicus Science Centre and Polish Radio – and a similar event in Lausanne from the History of Science Museum), and beaches (e.g., Techniquest's 1996 PanTecnicon program on the beaches of Wales). The product of a science center background is the nonverbal theater show from "Science Made Simple" called Visualise, an extravaganza of visually exciting science phenomena, accompanied by mime and music. Activities of this kind are also offered by science centers to the growing number of "science festivals" that have blossomed around the world. EUSEA (mainly Europe) and the Science Festival Alliance (mainly the USA) are two coordinating bodies with an international remit.

In Brazil, São Paulo's "Science Station" reaches out to street children in the Lapa quarter of the city with Project Clicar, an ICT-based project which provides youngsters with their only address: an email one. Meanwhile in California, the Cal State Long Beach Mobile Science Museum visits children of homeless Long Beach families as part of a science education camp. In Mexico City, Universum works with the "Office for Attention to Vulnerable Populations" to bring health topics and the underlying science to disadvantage people in educational and disability care organizations. The Boston Children's Museum takes family learning opportunities to low-income public housing developments through its Go Kids program.

Integrating traditional knowledge and science, The Bishop Museum in Hawaii reaches out to underserved schools throughout the Hawaiian islands through its program "All Together Now," which aims to integrate the science with cultural stories, combining Western science with relevant cultural knowledge and practice. In Montana, a program with similar intent reaches out to the indigenous American Indians through the Blackfeet Native Science Field Center. In Western Australia, Scitech from Perth has, since 2007, visited every remote Aboriginal community every other year with student workshops, teacher development materials, and resource kits. The program, which can extend more than 3,000 km from the home base, involves significant staff training in cultural competencies and safety matters.

Sometimes, outreach is only "across the street" – the Ontario Science Centre's Flemingdon Park project – or aims to capture audiences who may be frightened of science: the Science ABC sessions from Science Oxford are for everyone who has never studied science or who has forgotten what they ever knew! At other times, it reaches out over considerable distances: OMSI, the science center in Portland, Oregon, has an award-winning program which it operates with library partners to provide underserved rural communities with access to science workshops. The Oak Hammock Marsh Interpretive Centre in Manitoba has a Wetlands Outreach program which covers a vast geographic area across three Canadian provinces – and Scitech in Perth operates across many thousands of kilometers in Western Australia.

Supporting schools is perhaps the most common motivation for science museum outreach programs. Examples divide into two kinds:

those which enrich or complement an already well-established curriculum, bringing unusual resources and/or specialized expertise to the classroom, and those which compensate for deficits in equipment or pedagogy. In simplest terms, these two approaches are found in the richer and poorer countries of the world, respectively, but the distinction is by no means clear-cut.

The Unizul Science Centre in Richards Bay, South Africa, offers various outreach programs, one of which is explicitly "compensatory." Many high schools are struggling with large classes, limited equipment, and poorly qualified staff. The science center offers workshops at seven different rural locations to demonstrate practical work to matriculating students – work which is examined but seldom performed.

Of the "complementary" programs, there are many to choose from. Those interested in well-described examples could look at the Classroom and Assembly programs from the Science Center of Iowa, Des Moines, USA; the Bodyworks program from the Glasgow Science Centre, Scotland, UK; the Reach the Heights program from Techniquest, Wales, UK; Smart Moves, Science Play, and Maths Squad from Questacon, Canberra, Australia; Scientists on Tour from the Dundee Science Centre, Scotland, UK; Astronomy on Wheels and the Educator Loan Kit Program from the Fort Worth Museum of Science and History, Texas, USA; OMSI's widely dispersed "traveling programs" for schools and teachers; and the Talk Science professional development program for teachers from the Science Museum, London. Commitment to lifelong learning, involving both schools and communities, is often espoused by science centers, a notable example being the Exploratorium in San Francisco, USA.

Conclusion

Most science museums and science centers succeed in maintaining a "baseline" offering of outreach programs, normally including:

- Support for schools' classes, often with explicit built-in professional development for teachers
- Community projects intended to maintain the profile of the providing institution, often partnered with other family-friendly events
- Simple traveling programs (e.g., small-scale loan exhibits for classroom use, portable planetaria)
- Lecture programs, science cafés, and other "dialogue" style events

The more challenging and exciting examples of outreach are necessarily more resource-intensive and often tied to fixed-term grant funding, whether of a capital or revenue nature. Major assets such as sophisticated vehicles become increasingly expensive to maintain and operate and generally have a limited life engaging with the public. Programs focused on hard-to-reach audiences, whether for cultural or geographic reasons, require dedication on the part of the provider – both to the delivery and to the generation of recurrent funds for maintaining the operation.

Evaluating the impact of all this work offers the same challenges as the wider effort to understand the power of informal learning environments. All too often, the evidence for learning cannot be captured when the learner is exposed to the experience, and indeed, it is common for this evidence to become apparent only when a new context arises where the learner makes a connection with the earlier experience. Numerous individual outreach projects have been evaluated for their impact, with varying degrees of robustness, but no general study of this area appears to exist.

A further complication in assessing impact arises when an outreach project – as frequently occurs – has an evolving set of objectives during the course of its lifetime. Techniquest's "Comm Quest" project began as a public showcase for interactive science in partnership with the Commonwealth Secretariat at the Commonwealth Heads of Government meeting in Durban, South Africa in 1999. It then toured the country as an educational resource, with excursions into public domains (e.g., shopping malls), and a dozen years later, it was still being traveled – under the name SciQuest – as an interactive science exhibition for communities.

Science outreach is widely practiced by research institutes, universities, medical institutions, and bodies like NASA which have a major responsibility for the achievement of a nation's technological ambitions. Very frequently, they operate in partnership with science museums and science centers, seeing them either as delivery partners or as gatekeepers to the formal education system. Most frequently the motivation is to do with building the public's awareness and appreciation of medical, scientific, and technological research. These programs, too, are building bricks in the "community powerhouse."

Cross-References

- ▶ Café Scientifique
- ▶ Citizen Science
- ▶ Learning Science in Informal Contexts
- ▶ Museums
- ▶ Public Engagement in Science
- ▶ Science Circus
- ▶ Science Community Outreach
- ▶ Science Festivals

Science Olympiad

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The Olympiads are like the Olympics, but for academics, not sports. Unlike the Olympics which are held every 4 years, the Olympiads are annual events held in a different country each year. Further, the participation is limited to preuniversity students. These annual international Olympiads are held in a number of subjects: physics, chemistry, biology, junior science, astronomy and astrophysics, and mathematics, among others.

The Olympiads were initiated by teachers and academicians in USSR and the erstwhile east European nations about 50 years ago, in the late 1950s and 1960s. The Mathematics Olympiad was the first to be organized in 1959. Physics and Chemistry followed a decade later, in 1967 and 1968, respectively. Each of these began with half a dozen or less east European nations bringing together about five of their brightest students to a single location and posing a series of challenging tests. This trend has continued with the students being accompanied by two teachers who are called leaders and sometimes an additional observer teacher.

The theoretical tests are spare in nature. The number of questions is about 3–5 and the student is given 5 h to attempt them. Either one or two experimental tasks are assigned, and once again, the student is given ample time to complete them. The purpose is to test the student's creativity and innovation. The tests are designed by the host country. The leaders form the "jury" and vet the questions before these are presented to the students. To ensure confidentiality the leaders and the students stay in separate locations and are not allowed to meet during the testing period. The leaders are provided with the photocopies of their students' answer scripts and grade them independently of the host country. They are given an opportunity to discuss their evaluation vis-à-vis the host country's evaluation team during a moderation session. In other words the tests are ability and not speed tests and the process of evaluation is made as fair as possible.

Students who do well are awarded medals. Usually the top 10 % of the students are awarded gold medals, the next 12–15 % are given silver medals, and then those in the next 15 % slot are given bronze medals. In some of the older Olympiads, there is an additional category called honorable mention for those who did reasonably well but did not bag medals. The detailed scheme for each Olympiad is quite involved and the above percentages for medals are approximate. The overriding concern is to promote goodwill, and hence, there is no official ranking of nations.

The Olympiads have impacted the educational curricula of several nations. Numerous textbooks and problem books based on national selection tests have been published. Several of the problems have been published in leading peer-reviewed science journals. Special journals devoted to problems and competitions are currently published. Teachers and resource persons associated with the Olympiads have been invited to serve on panels to design school tests and to improve the course content.

There has been a steady increase in the number of Olympiads. The Biology Olympiad was started in 1990, the Astronomy and Astrophysics Olympiad in 2007, the Informatics in 1989, and the Earth Science Olympiad in 2007, to name a few. Regional Olympiads have gained popularity. The Asian Physics Olympiad was started in 1999 and now has over 20 participating nations. Many of these are "official" in the sense that there are carefully laid out rules and statutes and that the host nation routes its invitation through the nodal agency responsible for the selection of the team via a high-ranking government functionary, such as the minister of education. In contrast there are a host of private Olympiads.

The Olympiads are held in different countries from year to year. They have grown in size. The Mathematics and Physics Olympiads boast of close to a 100 nations. Each participating country pays a modest "entry" fee and pays for its travel. The expenses for the stay and excursions are borne by the host country. The Olympiad serves as an occasion to showcase the culture and educational strength of the host nation to teenage students who would become the future scientific leaders of their nation. Every attempt is made to maintain bonhomie, cheer, and goodwill. The Science Olympiads are a celebration of the best in preuniversity science.

Listed below are some helpful Olympiad websites:

www.Olympiads.hbcse.tifr.res.in for Olympiads
ipho.phy.ntnu.edu.tw, www.jyu.fi/ipho for International Physics Olympiad
www.icho.sk for International Chemistry Olympiad
www.ibo-info.org for International Biology Olympiad
www.ioaa2010.cn for International Olympiad on Astronomy and Astrophysics
www.ijso-official.org for International Junior Science Olympiad
www.imo-official.org/ for International Mathematical Olympiad

Cross-References

▶ Science Fairs

Science Outreach

▶ Scientist-School Interactions

Science Studies

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Keywords

Culture; NOS; Philosophy of science; Science wars; Social sciences; Sociology of scientific knowledge (SSK); STS

Science studies is an area of scholarship devoted to the understanding of science and its operations as well as its interactions with society. Though its borders are far from sharply defined, science studies is generally understood to encompass work done in any of the fields of history, philosophy, sociology, and anthropology of the natural sciences. Such work aims to understand, among other things, the conceptual, epistemological, social, and cultural aspects of the sciences and the communities of practitioners that pursue scientific research. These studies make up the core of the field. Other approaches include disciplinary work drawing from cognitive psychology, cultural and feminist studies, and other research and theoretical traditions. Scholars working within these various fields are most frequently interested in developing understandings of the natural sciences (e.g., physics, chemistry, biology, geology) but have also focused their attention on newer interdisciplinary fields such as biotechnology, biomedicine, computer and information studies, and technology itself as well as social science fields such as economics (Fuller 2005; Hess 1997; Sismondo 2009).

The field is sometimes referred to as "science and technology studies" in which case it goes by the acronym STS. This version explicitly adds technology to the mix, a move that not only places technology on equal footing with science but also acknowledges the recent trend by some scholars in the field to see science and technology as indistinct, recognizing that we have, in fact, entered a period where "technoscience" is perhaps a better description of what those engaged in scientific research actually produce. STS also serves, in some circles, as shorthand for "science and technology in society." Originally this denoted a distinctive approach in the field that sought to explore more closely the relationship between science and society (particularly to make science more accountable to public interests) in contrast to the epistemological and sociological practices of science in and of itself (Sismondo 2009). In the context of science education, this usage evokes the STS curricular movement of the 1970s and 1980s that situated science in the context of contemporary social issues, especially those related to the environment.

One of the primary goals of science studies, put simply, is to explain how science as an activity *works* using the methods of the social sciences and philosophy. The first systematic efforts to develop some extrascientific understanding of science in this way came in the field of philosophy where questions about the essence of knowledge extend back hundreds of years. The philosophers were later joined by historians, who sought to document the progress of scientific thought. While such efforts go back to the emergence of science as a clearly identifiable community of practice in the early 1800s, more formal efforts to chronicle the historical development of science, particularly with the aim of demonstrating its normative structure, came in the middle decades of the nineteenth century. From the mid-nineteenth century to the middle of the twentieth century, the history and philosophy of science stood alone as fields devoted to the understanding of science as a human activity.

It was only during the 1960s that science studies coalesced into an identifiable field. Important foundational work came from the sociologist Robert Merton (1910–2003), who articulated an early view of the social and cultural norms of science, and Ludwig Fleck (1896–1961). The work of Thomas Kuhn (1922–1996), however, particularly his seminal book *The Structure of Scientific Revolutions* (1962), was the catalyst that gave rise to science studies in something close to its current form. Kuhn's book, which offered what many saw as a radical account of scientific change over time, combined with the heightened attention to the role of science in society that came as a result of the massive government investment in scientific research during World War II and throughout the postwar period to shine a light on the functions of science. The new public investment in science and growing influence of technocratic government initiatives and outlooks led to the founding of new, interdisciplinary science studies programs in the United Kingdom that were originally designed to ease the transition to a society newly infused with high levels of science and technology (Edge 1995).

Although originally intended to engage in science education that would promote a humanized form of science more attuned to the needs of society, the new programs in the United Kingdom soon turned to more academic questions surrounding the very operations of science and the manner in which it generated new knowledge about the natural world. The most famous of these was the science studies program at Edinburgh University. Scholars in this program developed what came to be called the sociology of scientific knowledge (SSK) approach that called into question the authority and objectivity of science. Taking their cue from Kuhn's assertion in *Structure* that revolutionary changes in science occur by means other than rational consideration of empirical evidence, Edinburgh scholars such as Barry Barnes and David Bloor argued that the emergence of scientific theories is significantly influenced by the social and cultural commitments to which scientists adhere (Edge 1995).

It was this work that was largely responsible for what many referred to as the "science wars," which, in simple outline, consisted of sociologically inclined science studies scholars on one side who sought to problematize the certainty and authority that institutional science sought to project and scientists (largely) on the other side who resisted this critical examination of their enterprise and endeavored to expose what they believed was less-than-rigorous intellectual work. This genre of science studies, they argued, betrayed a lack of scientific understanding and ultimately demonstrated the vacuous nature of their assertions. A significant amount of the conflict centered on the "Sokal hoax" of 1996. The "science wars" largely passed out of attention not long after the turn of the twenty-first century. Science studies work, however, continues in all the fields mentioned above. Among the subsequent threads of scholarship still being pursued are laboratory studies that seek to carefully document the day-to-day production of knowledge, cultural histories of various disciplinary fields, and philosophical analyses that seek to understand the epistemological practices of science in its natural settings (Fuller 2005; Zammito 2004).

Research in science education and science studies has intersected in a number of ways beginning in the 1970s and 1980s. Two of the most prominent areas of contact have been related to science curriculum and pedagogical practice. With respect to curriculum, there has been, perhaps, no more sustained research focus than that dedicated to conceptualizing some view of what many have called the "nature of science" and incorporating it into the school curriculum. Work in this vein goes back at least to the World War II era with Harvard president James Conant's efforts to teach about the nature and process of science to Harvard undergraduates in the 1940s. At the precollege level, researchers following the recommendations of various national policy documents have similarly sought to capture the essence of science in order to place it in the curriculum with the belief that some understanding of the nature and process of science is key to a meaningful and socially relevant understanding of science. Although there appears to be consensus on the importance of understanding something about science and how it works, the accuracy and usefulness of the particular curricular portrayals of science advocated have been debated. Insights from the science studies literature have been central to these ongoing discussions.

Scholarship from science studies has led to pedagogical experimentation as well. Recent work on seeing science as a practice consisting of discipline-specific conceptual frameworks, specialized vocabulary, norms of argumentation, standards of evidence, representational tools, and so on has prompted science education researchers to examine the ways classroom instruction might be tuned to simulate certain aspects of scientific practice. Research on student modeling and argumentation are two prominent areas of such work. The history of science (another domain within science studies) has been used as a resource for alternatives to traditional instruction in science as well. Historical case studies or narrative accounts of scientific advance have long held out promise of productively engaging students through a more humanistic approach to science teaching, although the potential of this approach to scale up has not yet been demonstrated.

Beyond the sphere of the school science classroom, science education researchers have explored questions of scientific literacy or how citizens engage with science in their daily lives using insights from various science studies fields. Conversely, science studies scholars – particularly those in the history of science – have begun to examine how pedagogical practices and texts have emerged and functioned in the reproduction of various communities of scientific practice through history. Such work highlights the value and productivity of the growing mutual recognition of the science studies and science education research communities.

Cross-References

- ▶ Action and Science Learning
- ▶ History of Science
- ▶ NOS, Measurement of
- ▶ NOS: Cultural Perspectives

- ► Paradigm
- ► Sociology of Science
- ► Socioscientific Issues

References

Edge D (1995) Reinventing the wheel. In: Jasanoff S, Markle GE, Peterson JC, Pinch TJ (eds) Handbook of science and technology studies. Sage, Thousand Oaks, pp 3–24
Fuller S (2005) The philosophy of science and technology studies. Routledge, New York
Hess DJ (1997) Science studies: an advanced introduction. New York University Press, New York
Sismondo S (2009) An introduction to science and technology studies. Wiley-Blackwell, Malden
Zammito JH (2004) A nice derangement of epistemes: post-positivism in the study of science from Quine to Latour. University of Chicago Press, Chicago

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Science Teacher Education

- ► Primary/Elementary Science Teacher Education
- ► Secondary Science Teacher Education

Science Teacher Education in Mainland China

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Keywords

Science Education in the Non-West

Introduction

As in many other countries, the science teacher education system in mainland China is a part of the teacher education system of the country. Chinese science teacher education system has undergone tremendous transformation and change since its advent in the early twentieth century, from first transplanting foreign teacher education systems one after another, then through the process of indigenization, to finally forming "the Chinese model of (science) teacher education" (Li 2012, p. 417) with distinguishing features of its own. Today, Chinese science teacher education is very much *sui generis* in that on the one hand it has adopted and indigenized both Anglo-American elements and Continental European elements, including Japanese and Russian influences, and in that on the other hand it has inherited "Confucian epistemology and pragmatism" (Li 2012, p. 417).

In this entry, I first present a historical context in which I briefly describe how Chinese science teacher education system was initially in place. Then, I provide a detailed discussion of the reform and current state of Chinese science teacher education, followed by particular consideration of elementary science teacher education and then secondary science teacher education. Next, I highlight some problems and/or challenges that have arisen in the new millennium that have faced Chinese science teacher education in mainland China. Finally, I conclude with a summary, characterization, and conceptualization of Chinese science teacher education.

Historical Context

In ancient China, there were both public (official) and private schooling systems with teachers transmitting Chinese culture for more than 4,000 years without a break. However, there had been no specialized teacher education system in China until around the turn of the twentieth century when the Western teacher education system was transplanted into China via copying the then Japanese teacher education system (which in turn mainly emulated those of Germany and France at that time).

According to Li (2012), a noted researcher on the Chinese history of education, now working with the Chinese University of Hong Kong, the modern Chinese (science) teacher education system has gone through four stages: (1) establishment (1897–1911), (2) institutionalization (1912–1949), (3) reinstitutionalization (1949–1993), and (4) professionalization (1993–present). During the first stage and the first decade of the second stage, Chinese science teacher education was heavily influenced by Japanese science teacher education in terms of system and program and by taking in pedagogical ideas and theories from Germany, especially Herbart and Herbartianism. Thus in preparing school teachers of science, student teachers would study Herbartian pedagogics (including didactics or Didaktik), educational psychology, and subject didactics (Fachdidaktik), the trio core courses in pedagogical studies of teacher education programs that have since set the tone for and had a lasting impact on Chinese science teacher education until today.

The first institute for training school science teachers, *Nanyang Gongxue*, was founded in 1897 in Shanghai. *Nanyang Gongxue* (the forerunner of Jiaotong Universities in Shanghai and four other cities in mainland China and one in Xinzhu, Taiwan) consisted of four schools: a normal (i.e., teacher training) school, an affiliated elementary school, a secondary school, and a college of higher learning. Following *Nanyang Gongxue*, in 1902 several independent normal schools were established in Wuhan, Hubei province; in Nantong, Jiangsu province; and particularly in Beijing, where, what was called the "Institute for Normal Education" (later to become Beijing Normal University) was added to the newly established Peking University (*Jingshi Daxuetang*). Peking University, the first modern national university in China, had been founded in 1898 by the government of the late Qing dynasty (Li 2012).

These newly founded normal schools across the country and the Institute for Normal Education within Peking University (*Jingshi Daxuetang*) laid the foundation for establishing a national system of teacher education. Thus, in 1902 and 1903, the government of the late Qing dynasty promulgated the first national educational legislation, thereby creating a modern school system based on the model borrowed from Japan. According to the newly promulgated legislation (*Guimao Xuezhi*) of 1903, every county or prefecture should open a junior normal school and every province should open a senior normal school, in order to train teachers for local elementary and secondary schools, respectively (Li 2012). These normal schools were completely transplanted from Japan in respect of their structures, contents, and even the style of school buildings.

Beginning in the early 1920s during the second stage of institutionalization (1912–1949), China began to turn to the USA for a model of education in general and of science teacher education in particular. This was partly because of Japan's aggression to China, which aroused strong feelings among Chinese people against everything Japanese and partly because a large group of US-educated Chinese scholars returned to work in Chinese universities and government agencies and came to dominate Chinese educational circles. It should also be noted that US emerging educational sciences, including curriculum theories and science education research, especially John Dewey's modern theory of education as opposed to the so-called traditional theory of Herbart, attracted many Chinese educators at that time. As a result of these factors, China finally jettisoned the school system that was copied from Japan in 1922, and in its stead introduced a new school system, a 6-3-3-4 system, which was modeled on the US school system. For the following three decades from the early 1920s to the late 1940s, Chinese science teacher education was likewise modeled on the US science teacher education. In correspondence with this, the textbooks of science methods courses in Chinese teacher education programs at colleges and universities at that time were full of US educational ideas and theories, although the titles of such textbooks were still *Jiaoxuefa* (i.e., Didactics) in Chinese, as before.

After the Communist Party of China took power in 1949, during the first decade of the third stage of reinstitutionalization (1949–1993), there was another dramatic shift in education, including science teacher education. This time China sided with the Soviet Union in the socialist camp. As the ideology of the state changed, so did the teacher education system, the dominant pedagogy, and science education programs as well. In terms of the science teacher education system, in 1952 the Chinese communist government issued a policy of restructuring higher education throughout mainland China, and under this policy, a closed, independent teacher education system modeled on the Soviet system was established. All primary school teachers were trained in closed, independent normal schools, who only studied some high school level science courses. All secondary science teachers were prepared by closed, independent normal colleges and universities, with student teachers who would be teaching in junior high being trained in 2–3-year normal colleges, while student teachers who would be to teach in senior high being trained in 4-year normal colleges and universities. In this system of science teacher education, secondary (both junior and senior) science teachers were trained in separate departments of the normal colleges and universities, such as the department of physics, department of chemistry, and department of biology. In this way, for example, a student teacher of physics education had to study physics courses exclusively for 4 years in addition to courses on politics, physical education, foreign languages, and, of course, pedagogical studies. This rigid structure of science teacher education has remained basically unchanged until today, although the whole system of science teacher education has become more open and flexible, as described in the following sections.

Reform and Current State in Science Teacher Education

Reform in Science Teacher Education

Since the start of the fourth stage of professionalization (1993–present) mentioned above, science teacher education has witnessed a major transformation again as the Chinese government began to “embrace a sweeping wave of neo-liberal ideology, e.g., marketization, privatization, and decentralization” (Li 2012) in 1993. This shift in policy has effected considerable change in the (science) teacher education system in the following respects.

First of all, the Law of Teachers of the People’s Republic of China, the first such law in mainland China since 1949, was enacted in 1993, signaling a new era of teacher education reform. The law regulates the legal rights and responsibilities of teachers as professionals and mandates a national teacher certification system.

Second, the Chinese government restructured the (science) teacher education system by introducing a mechanism of competitiveness in conducting teacher education, that is, entailing a teacher education system that is chiefly reliant on independent normal colleges and universities while allowing comprehensive universities to develop teacher education programs. Meanwhile, within the normal colleges and universities, teacher education programs and non-teacher education programs go hand in hand, thus breaking the closed teacher education system that originated from the Soviet Union.

Third, two new science teacher education programs have been initiated since the 2000s. One is an undergraduate science teacher education program that aims to prepare integrated science teachers for primary school and junior high school as the current new science education reform dictates. At the time of writing (2013), there are 65 colleges and universities that provide such a program. The second new science teacher education program is intended for practicing science teachers as well as for newly graduated bachelor degree holders who are encouraged to pursue a master’s degree program in science teaching and even a DEd program in science teaching, in order to enhance science teachers’ status and level of professionalization.

And finally, a discussion of the change that has arisen in science teacher education research and development is in order here. As indicated above, science teacher education research and development in mainland China takes the form of developing subject didactics of science disciplines, such as didactics of physics, didactics of chemistry, and didactics of biology, which is congruent with subject specialization in school science teaching. This is a tradition formed in the early 1900s when China introduced German pedagogics and didactics into the pedagogical courses of teacher education and reinforced later in the 1950s when Soviet pedagogy and didactics were introduced again. Therefore, most science teacher educators in colleges and universities call themselves didacticians of physics or chemistry or biology (Ding 2013). Similarly, most of them identify themselves with their subject associations of science subjects, such as the Association of Physics Didactics, rather than the newly established National Association for Science Education founded in 2009.

However, in respect of the research and development of subject didactics of science in mainland China, a new trend has occurred over the past decade in that didactics has met curriculum studies and the two have merged and been integrated to become a new hybrid pedagogical discipline for science teacher education. This situation has happened in the context of the new curriculum reform that began around the turn of the new millennium when curriculum studies were reintroduced from the USA in the 1990s. Thus curriculum studies since have flourished and developed significantly, and this has paved the way for some didacticians of physics, of chemistry, and of biology to take ideas from curriculum studies into textbooks of subject didactics of sciences intended for prospective and in-service teachers of science. Correspondently such textbooks more and more have taken the titles of “curriculum and didactics of physics” (of chemistry, of biology, and even of science), a newly formed characteristic of science teacher education less seen in other countries.

Elementary Science Teacher Education

Like elementary science, elementary science teacher education has had a long past but a short history in China, as is the case in many other countries. Before 2000, elementary science was called “nature” (*Ziran*) as one of the auxiliary subjects in elementary schools and was generally taught by nonspecialist teachers with a tenuous background in science. As a matter of fact, “nature” was on the school timetable but not taught in many schools, especially in rural primary schools. It depended on whether the school principal placed importance to the subject or not. This was the case mainly because elementary science teachers were not specially trained, although some of them might have gained good in-service training while in teaching. For example, in the late 1970s and throughout the 1980s, Brenda Lansdown (1904–1990), a Harvard professor of science education specializing in primary science, came to China for academic visits many times and gave several workshops on primary science teaching in Beijing and other cities. This prepared a large cohort of primary science teachers from across the country who have become specialist primary science teachers and even today continues to have an impact on the professional development of primary science teachers.

Around the new millennium, the science curriculum reform for the 9-year compulsory schooling decided that “primary science” in place of “nature” as a required subject would be taught from grade 3 to grade 6 in all primary schools. Since then many normal colleges and universities have begun to provide 4-year teacher education programs for primary schools as demands for the qualifications of primary school teachers rise. In these teacher education programs, some of the student teachers select to study more science courses so that they will serve as specialist primary science teachers. This is the case especially in metropolitan cities such as Beijing and Shanghai, as well as provincial capitals and coastal cities. As a result, more and more specialist primary science teachers are prepared by primary science teacher education programs in colleges and universities, although it should be acknowledged that there are many 2–3-year local (normal) colleges still turning out elementary teachers who receive less training in science.

The current science curriculum reforms have also provided a new impetus for the professional development of primary science teachers. Primary science teachers in mainland China consist of two cohorts, with one being specialist science teachers who have stood out as excellent primary science teachers or graduated recently from elementary science teacher education programs in normal colleges or universities and the other being nonspecialists who teach other subjects like mathematics as well as science. So at school level, the specialist primary science teachers may serve as science coordinators helping other teachers improve their science teaching, while at the district, county, and/or municipal levels, some of the outstanding specialist science teachers are selected as science teaching researchers (*Jiaoyanyuan*), whose tasks are to provide in-service training or professional development for primary science teachers.

Secondary Science Teacher Education

Preservice Science Teacher Education for Secondary School. In secondary schools, grades 7–9 are junior high school and grades 10–12 senior high. Except in Zhejiang province and in Shanghai where school science in junior high schools has been taught as an integrated subject since the mid-1990s, subject-based science subjects, i.e., physics, chemistry, biology, and partly geography (natural geography), are taught by different subject teachers. In senior high schools, science is always taught as separate science subjects by different subject teachers. Under this circumstance, preservice science teacher education programs in colleges and universities are conducted in separate departments (or colleges/schools) of sciences in collaboration with the department (or college/school) of education, a tradition that dates back at least to the 1950s when China restructured (science) teacher education system patterned after that of the Soviet Union. For example, all student teachers in physics study in the department of physics, while all student teachers in chemistry study in the department of chemistry, and so on. The departments of physics or chemistry provide subject-based science courses and subject didactics courses (didactics of physics, didactics of chemistry, etc.), while the department of education gives other courses on pedagogical studies, including pedagogics, psychology of education, and educational technology. In many cases, both junior and senior high school science teachers are prepared by 4-year teacher education programs, conferring BSc on graduates. But in some rural areas, junior high school science teachers usually receive 2–3 years college education in local normal colleges, as was the case for all junior high school science teachers before 2000.

Over the past decade or more, preservice science teacher education for secondary schools in mainland China has seen new trends. This is partly as a result of the expansion in enrollments of postgraduate education and partly due to the difficulty of employment for some of master's degree students in science. First of all, some postgraduate students with a master's degree in science are encouraged to work as science teachers, and they have come to form a new cadre of school science teachers, especially in what are so-called model high schools (*Shifan Gaozhong*) in towns and cities throughout the country. Second, some outstanding high schools in metropolitan cities such as Beijing, Shanghai, and others have recently even attracted PhDs in science or in science education to their teaching force. Third, in both undergraduate and postgraduate science teacher education programs, some of the student teachers are offered the opportunities to study half a year or 1 year as exchange students in the universities of industrialized countries on government or interuniversity scholarships, thus facilitating the internationalization of science teacher education for mainland China. Hopefully, there is every reason to expect that these new trends in preservice science teacher education will improve the quality of science teacher education significantly.

Professional Development of Secondary Science Teachers. In-service training/education or professional development for teachers of science (and other subjects) also has a significant place in China. It is also unique in that while it is rooted in both foreign theories and practices which have been indigenized, it is simultaneously predicated on Chinese traditions and experiences.

To start with, as there is only a short period of time (6–10 weeks) devoted to professional experience or practicum teaching in schools for preservice student teachers, beginning science teachers in mainland China usually have an induction period of 1 or 2 years in schools where they are employed to work, which is the so-called mentoring practice on the job. During this period, beginning science teachers are assigned to work with experienced teachers as dyads, thus forming a relationship of master and apprentice. This kind of "cognitive apprenticeship" is a very effective experience of learning to teach for beginning science teachers, because experienced teachers as senior people with wisdom are highly respected in the Confucian culture.

Secondly, the established system of the teaching researcher (*Jiaoyanyuan*, hereafter referred to as *JYY*) has been in place since the mid-twentieth century and is a significant feature of professional development. Who is a teaching researcher or *JYY*, and what does he or she do in the professional development for science teachers? (Ding 2013)

A teaching researcher or *JYY* is not a member of staff in any school. He or she works with a unit (i.e., the division of teaching research, or *Jiaoyanshi*) embedded in the administrative body of education at the various levels of the county, municipality, or province. For example, in Beijing, there are more than 120 teaching researchers of physics, chemistry, and biology at secondary school level, who are working with the district educational bureaus or with Beijing Municipal Educational Commission. These teaching researchers or *JYYs* used to be excellent school teachers, and now they are responsible for the professional development for science teachers (Hewson 2007) in the field of their own school subjects.

As teacher educators of school science teachers, teaching researchers or *JYYs* are different from science teacher educators in colleges and universities in that the former (JYYs) are practitioners with both rich experience and theoretical knowledge of pedagogical studies and they focus on practitioner research into science teaching, curriculum, evaluation, and professional growth and development for science teachers. On the other hand, the latter are academics much more interested in educational theory and research than the former. Specifically, the roles and/or responsibilities of teaching researchers or JYYs of science in mainland China include the following aspects:

1. **Research**. Teaching researchers or *JYYs* of science conduct research into curriculum, teaching, assessment, and professional growth and development for science teachers in ways that concentrate on the practical issues and problems in the above areas in their school subjects. For *JYYs* of science, the practitioner research they conduct is often done *with*, rather than *on*, school science teachers, and findings resulting from such research feed back to the *guidance* and *service* they offer to science teachers in order to improve science teaching and learning and to provide quality assurance of schooling in science.
2. **Guidance**. *JYYs* of science provide professional *guidance* for science teachers under his or her jurisdiction. Guidance rendered by *JYYs* concentrates on two cohorts of teachers: novice and leading teachers, for the reasons that the novice teacher will soon act as a qualified teacher, while the leading teacher will share his or her successful strategies or experiences with other teachers. For example, a *JYY* of physics at the Beijing municipal level may call a daylong professional meeting, whereby about 40 teaching researchers of physics and some of the leading physics teachers from the various districts and counties of Beijing (there are 14 districts and two counties within the city of Beijing) come together for learning about and discussing how inquiry-based physics teaching and learning is conducted in the classroom. These kinds of learning activities are often connected with the current curriculum reform policies, which school science teachers are required to implement and enact through the mediation of *JYYs* of science.
3. **Service**. It is also incumbent on *JYYs* of science to offer *service* to individual science teachers or a particular group of teachers to improve teaching quality by sitting in on and observing science lessons. For instance, if an experienced teacher of chemistry is asked by his or her school head to conduct an open

lesson (*Gongkai Ke*) for his or her colleagues to observe from the school or even from many schools in the district so that other teachers may learn from it, the *JYY* of chemistry in question is surely invited to give advice as regards how to best use the situation. Service afforded by *JYYs* of science also comes in the form of providing testing papers in school science subjects, for example, in the midterm or final examination each school year at county or district level.

Thirdly, the National Teacher Training Project (*Guopei Jihua*) has been initiated jointly by the Ministry of Education and the Ministry of Finance of China since 2010, whereby hundreds of thousands of practicing science teachers (and other subject teachers) have been selected to train in order to enhance the overall quality and professionalism. The National Teacher Training Project consists of two parts: the Project of Exemplary Teacher Training and the Project of Rural Key Teacher Training in central and western China. The provisions of the training are mainly located in normal colleges and universities, but sometimes also in leading high schools, with teacher trainers including university teacher educators, outstanding *JYYs*, and leading school principals and teachers of various subjects.

Problems and/or Challenges

In writing this entry, several pressing problems and/or challenges in respect of science teacher education in mainland China have come to mind. First, although science teacher education as indicated above has formed a unique Chinese model of (science) teacher education (Li 2012), can we say that this model is able to meet the needs of preparing high-quality teachers of science for mainland China? Second, inquiry-based science teaching and learning is singled out as one of the most important objectives of school science education both in mainland China and internationally. This is obviously a big challenge for both Western countries and China as well. Can the current Chinese science teacher education reform meet the challenge? Third, Chinese science teacher education research has adopted the tradition of German Didaktik (Fischler 2011), and meanwhile it has also accepted the Anglo-American tradition of science education research. In recent years, Chinese subject didacticians as science teacher education researchers have tried to integrate both the traditions in order to form a hybrid "curriculum and didactics of science" for various school subjects of science. Obviously, this seems to be another rigorous challenge for Chinese science teacher educators. To what degree can they succeed in making the integration? There are, of course, many other serious problems and challenges facing Chinese science teacher educators, but these problems and challenges stand out more manifestly and awaiting being addressed more urgently.

Concluding Remarks

Counting *Nanyang Gongxue* as the very first normal school that offered science teacher education in 1897, Chinese science teacher education has since undergone 116 years of development so far. The past century has witnessed a succession of identifiably historical pathways of science teacher education, each of which was appreciably marked by learning from other countries, sticking to China's cultural tradition, and adapting to social needs and changes influenced by a complexity of contemporarily political, economic, and educational factors. By integrating various elements from Japanese, Continental European, Russian, and Anglo-American models of science teacher education, there seems to have formed a *sui generis* Chinese model of science teacher education, based on Confucian epistemology that emphasizes the conception of "Chinese harmonism," expressed in the Confucian idea of "seeking for harmony but not the sameness" (*he er butong*) (Wang 2013). "With its core features of independence, openness, adaptability, and diversity based on Confucian pragmatism and epistemology," the Chinese model of science teacher education, despite its problems and challenges, "can provide alternative ways of thinking about the reform and change" (Li 2012) of science teacher education in the globalized world and, hopefully, will contribute to world science teacher education in the future.

Cross-References

- ▶ Didaktik
- ▶ Pedagogy of Teacher Education
- ▶ Science Education in Mainland China

References

Ding B (2013) The roles of subject didactics of sciences in science teacher education in mainland China: voices from inside and outside of the disciplines. Paper presented at the EASE 2013 conference, the Hong Kong Institute of Education, Hong Kong, 4–6 July 2013

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

Hewson PW (2007) Teacher professional development in science. In: Abell SK, Lederman NG (eds) Handbook of research on science education. Routledge, New York

Li J (2012) The Chinese model of teacher education: retrospects and prospects over a century. Front Educ China 7(3):417–442

Wang Z-H (2013) Process and pluralism: Chinese thought on the harmony of diversity. De Gruyter, Berlin

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Science Teachers' Professional Knowledge

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Keywords

Science teachers' professional knowledge; Subject-specific knowledge; Teacher knowledge

Introduction

Science teachers' professional knowledge, or science teachers' knowledge, is a specific category of "teacher knowledge." Understanding the nature of teacher knowledge (science teacher knowledge in particular) and how it develops is important not only in (science) education research but also in (science) teacher education processes and practices.

Conceptualization of Teacher Knowledge

The meaning of "teacher knowledge" as a construct has evolved over time as it has been interpreted and cast in differing ways from diverse perspectives by different scholars. The main tension that underlies the understanding of the nature of teacher knowledge can be traced back to the dichotomy between theory and practice. With an interest in the epistemological aspects of research programs on teacher knowledge, Fenstermacher (1994, p. 3) made a distinction between "the knowledge that teachers generate as a result of their experience as teachers" and "the knowledge of teaching that is generated by those who specialize in research on teaching." He designated the former as "teacher knowledge: practical" and the latter, "teacher knowledge: formal." He argued that both theoretical and practical knowledge can enjoy legitimate epistemological status in knowledge claims as long as the demands for justification are meet.

Most research programs in the 1960s and 1970s were concerned with formal knowledge and involved understanding teacher knowledge from a theoretical or propositional stance. In these research programs, teachers were the objects of research, the "known" in Fenstermacher's term, and the researchers often saw themselves as producer of knowledge about effective teaching. The 1980s saw the rise of several new research programs with a particular interest in teachers' action in practice and the beginning of the shift in focus from propositional to practical knowledge. In these research programs, teachers were seen as the "knower" and the coresearcher or coproducer of knowledge about teaching (e.g., teacher as researcher). Researchers adopted various terms to refer to teacher knowledge, each emphasizing a particular characteristic of teacher knowledge. These terms included "personal practical knowledge," "professional craft knowledge," "practitioner knowledge," "knowledge in action," and "local knowledge."

It would be more productive to see Fenstermacher's distinction as a heuristic device in analyzing teacher knowledge claimed in various research programs rather than as exclusive categories that reinforce the dichotomy of theory and practice. Teacher knowledge is a complex construct in which knowledge and beliefs, conceptions, and intuitions are intertwined. Practical knowledge (such as routines and procedures) and propositional knowledge (such as theories, concepts, and principles) are often interrelated in teaching practice. A comprehensive review of perspectives on teacher knowledge and how it develops is offered by Munby et al. (2001).

Subject-Specific Knowledge and Science Teachers' Professional Knowledge

In an attempt to answer the question "what knowledge is essential for teaching?" Shulman and his colleagues based their research program on studying specialized knowledge for teaching in different subject areas. Shulman (1987) proposed seven categories of teacher knowledge: (a) content knowledge; (b) general pedagogical knowledge; (c) curriculum knowledge; (d) pedagogical content knowledge (PCK); (e) knowledge of learners and their characteristics; (f) knowledge of educational context; and (g) knowledge of educational ends, purposes, and values and their philosophical and historical grounds. Shulman's model made an important contribution to the research on teachers' subject-specific knowledge and has promoted the idea of a distinctive knowledge base for teaching as a profession.

Building on Shulman's theoretical framework and other researchers' work in the field, Abell (2007) proposed a modified model for mapping research on science teacher knowledge. This model highlighted the relationship between general pedagogical knowledge (instructional principles, classroom management, learners and learning, and educational aims), knowledge of context (students, school, community, and, districts), science subject matter knowledge, and pedagogical content knowledge for science teaching. She described science subject matter knowledge as including syntactic knowledge (knowledge of scientific inquiry skills and investigations) and substantive knowledge (knowledge in chemistry, physics, biology, and earth and space science). Pedagogical content knowledge for science teaching includes orientations toward teaching science, knowledge of science learners, knowledge of science curriculum, knowledge of science instructional strategies, and knowledge of science assessment.

Pedagogical content knowledge (PCK) is conceived as a specific form of teacher knowledge. Researchers who ground their work on pedagogical content knowledge find it a unique concept in promoting the professionalization of teaching. It is different from content knowledge in that it emphasizes the particular context of teaching and the interaction between teacher and student. It is also different from general pedagogical knowledge, because it is closely related to teaching particular subject matter. However, there has been more controversy regarding the connotations of pedagogical content knowledge than the definitions of science subject matter knowledge. Researchers have different views on the composition of pedagogical content knowledge, and they interpret the elements of this concept in different ways.

Implications for Science Education Research and Science Teacher Education

Research programs on science teacher knowledge have included both practical and propositional knowledge within the knowledge base for teaching. Teacher knowledge is a multidimensional concept. As a result, research programs adopt multiple instruments and methods. In some areas, such as science teacher subject matter knowledge, researchers share more common language in elaborating terminologies, describing theoretical frameworks, and comparing findings. In areas like pedagogical content knowledge, where researchers still do not agree about terminologies and methodologies, research programs are less cohesive, and researchers continue to seek common ground and to develop a research agenda both conceptually and methodologically. Despite these differences, researchers share the ultimate goal of improving student learning by improving teaching practice. It is hoped that understanding different aspects of teacher knowledge and their relationships will contribute to substantial improvement of teaching practice.

How the understanding of teacher knowledge (science teacher knowledge in particular) informs teacher education programs and policies is an important question. Teachers develop their knowledge from diverse sources, including daily practice and experiences, formal teacher education courses, and professional development. Recognizing that knowledge gained from all these sources can be integrated by teachers to form a conceptualization that might guide their teaching practice, teacher education program design and policy making have experienced a transition from emphasizing subject matter knowledge understanding through the specialist nature of pedagogical content knowledge. At the heart of science teacher education and development is the need to pay careful attention to not only what professional knowledge is but also how it develops and changes over time.

Cross-Reference

- ► Pedagogical Content Knowledge in Teacher Education
- ► Teacher Professional Development

References

Abell S (2007) Research on science teacher knowledge. In: Abell S, Lederman NG (eds) Handbook of research on science education. Lawrence Erlbaum Associates, New Jersey, pp 1105–1149

Fenstermacher GD (1994) The knower and the known: the nature of knowledge in research on teaching. Rev Res Educ 20:3–56

Munby H, Russell T, Martin AK (2001) Teacher' knowledge and how it develops. In: Richardson V (ed) Handbook of research on teaching. American Educational Research Association, Washington, DC, pp 877–904

Shulman LS (1987) Knowledge and teaching: foundations of the new reform. Harv Educ Rev 57:1–22

Science Teaching and Learning Project (STaL)

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Keywords

Case writing; Critical reflection; Professional learning; Professional practice; Reflective practice; Teacher thinking; Teachers as researchers

Science Teaching and Learning Program

The Science Teaching and Learning (STaL) program is the result of a collaborative project between the Catholic Education Office Melbourne, Australia, and the Faculty of Education, Monash University. The program aims to provide professional learning that supports the development of science teachers' practice (across years K-12), both individually and collectively (Berry et al. 2009). The program challenges teachers' existing understandings about conditions which enhance quality science learning and supports teachers to critically reflect upon, research, and report their understandings of their teaching and develop new knowledge of practice (Loughran 2006). To achieve this, teachers are provided with time to trial new ideas, information to consider alternative practice, and opportunities to both discuss their learning and recognize the emergence of new professional insights. The culmination of this knowledge resides in participants constructing and sharing "cases" of reflective practice drawn from their resultant classroom experiences.

Underpinning Program Principles

A number of assumptions about teacher professional learning underpin the STaL program and therefore shape the program's structural design and approaches to teacher learning. The first assumption is that change in practice occurs most effectively when it is self-directed and focused on individual needs and concerns. Therefore, placing the ownership of the learning directly in the hands of the teachers themselves is a guiding principle which underpins facilitator behavior in the program. Secondly, teaching is seen as problematic. Through the STaL program, science teaching is presented as dilemma-based requiring teachers to continually make judgments about what are appropriate actions in a given situation at a given time. Following from this is the assumption that there is not just one way of doing teaching (Loughran 2010). Each participating teacher is expected to hold some commitment to change and bring their expert judgment to bear on how change might be implemented in their practice.

Working from these assumptions the program seeks to empower participating teachers to identify alternative approaches in science teaching and recognize the impact of these approaches on student learning. It seeks to assist teachers to articulate explicitly what they value in their science teaching and encourage them to observe or notice any tensions which exist between what they say they value and what they actually do in their practice (Smith 2010). The program also seeks to support teachers to consider and create new conditions for learning in their own classrooms which realign professional thinking about quality science teaching with practice.

Conditions are established within the program to specifically attend to the learning needs of teacher participants. These conditions include realistic time for learning, interactive workshops, school-based support, and specific program time devoted to case writing. The program is spread across the school year as a 5-day program and takes place in two blocks of two consecutive days and a final day devoted solely to teacher case writing. Teachers are accommodated overnight for each 2-day program, demonstrating an explicit valuing of teachers as professionals and providing extended opportunities, both formal and informal, for teachers and facilitators to work and talk together. Sessions which explore a variety of aspects of science teaching and learning are conducted throughout the program, and teachers are encouraged to discuss and explore ideas in relation to their own teaching context and across the different contexts of primary and secondary schooling. A minimum of two teachers from each school are expected to attend the program, to assist with embedding teacher learning within a school context once the program itself has concluded.

School-Based Aspects of the Program

School-based meetings with program facilitators are conducted regularly throughout the program and are a valued and integral part of the program's design and philosophy. These school-based meetings provide an opportunity for participating teachers to reflect on areas of their science teaching so that they can identify the aspects of their practice which they want to understand more about and enable them to collect data from their classrooms related to their specific science teaching concerns. The discussions which occur in these meetings potentially stimulate rich insights for each teacher into their teaching and their students' learning of science (Berry et al. 2009). These discussions assist teachers to identify the aspects of their practice which they would like to share and to clarify their ideas in preparation for case writing.

Case Writing

The use of cases within the STaL project assists teachers to sharpen the focus of their practice on the learning of students and in turn enables them to see their own teaching through different eyes. The cases, which are published in a book form, help teachers to articulate what were previously implicit beliefs or feelings about practice (Lindsay 2012). The cases then provide a vehicle for sharing teacher knowledge from which other teachers can learn.

Case writing has a significant impact on participants as having their work published affirms them as professionals and affirms the specialist knowledge that they hold as teachers.

Cross-References

- ▶ In-Service Teacher Education
- ▶ Teacher Professional Development
- ▶ Teacher Research

References

Berry A, Loughran J, Smith K, Lindsay S (2009) Capturing and enhancing science teachers' professional knowledge. Res Sci Educ 39:575–594

Lindsay S (2012) Valuing scientific literacy. In: Keast S, Loughran J (eds) Exploring scientific literacy. Monash Print Services, Melbourne, pp 1–3

Loughran J (2006) Why cases? In: Loughran J, Berry A (eds) Looking into practice, cases of science teaching and learning. Monash Print Services, Melbourne, pp 7–10

Loughran J (2010) What EXPERT teachers do: enhancing professional knowledge for classroom practice. Allen & Unwin, Australia

Smith K (2010) Learning to listen or listening to learn? The role of awareness in shaping practice. In: Berry A, Keast S (eds) Looking into practice: cases of science teaching and learning, vol 2. Monash Print Services, Melbourne, pp 4–7

Science Theater/Drama

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Keywords

Theater

Drama/Theater in Science Education

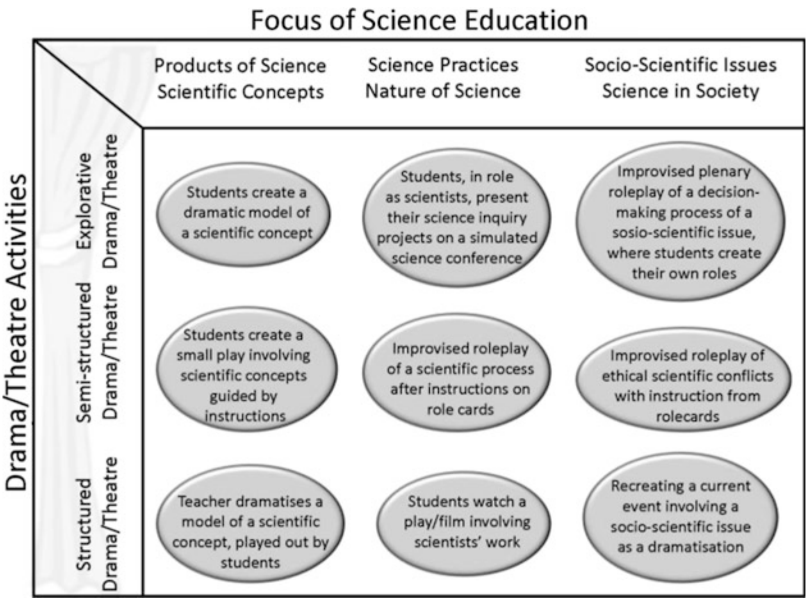
The liberal arts and science have traditionally been seen as two very different subject areas, indeed different cultures, and education seems to maintain this divide. However, they have much in common. Imagination and creativity play a critical role both in learning an art form such as drama and in learning science. Thus, these two disciplines can mutually help and inspire each other.

"Theater" and "theory" have a common etymological root in the ancient Greek verb "theorem," which means to see, to view, or to behold. The theoria in ancient Greece viewed the dramas of everyday situations and extracted truth. This kind of knowing, attempting to draw universal generalizations based on specific observation, is also viewed as a key epistemological feature of scientific explanations. The use of drama in a well-considered manner, guided by reflective science teachers, may provide empowering learning environments for students.

Perspectives of Science Education

There are many different examples of how drama and theater activities can be used in science education (see Fig. 1). Most traditionally, students explore the academic side of science with its products, models and scientific concepts that explain natural phenomenon. Within the known framework of scientific theories, students may, for instance, play electrons in a circuit to illustrate and get a deeper understanding of the scientific concept of electricity. The process of transferring the model or description from the textbook to a three-dimensional live model requires the students to reconceptualize their knowledge. Through the process of social interaction that involves both verbal and physical activities, students increase their understanding. In addition, teachers have an expanded ability to assess students' understanding immediately under the course of the activity and give feedback to deepen the students' understanding.

Another important perspective of science education is scientific processes, which involve understanding science practices and nature of science. Scientific processes are centrally concerned with scientists' experimental and



Science Theater/Drama, Fig. 1 Overview of aspects of theater and drama activities in science education, inspired by Ødegaard (2001, 2003)

conceptual work, both in the laboratory and elsewhere. The students' only experience of this is often through predesigned laboratory exercises, which do not authentically reflect the scientific process. In particular, the important communication process between researchers, in which discussion and debate occurs, is seldom mentioned. Letting students take on the mantle of an expert and role-play scientists doing scientific inquiry reveals many aspects, both practical and social, of scientific practices to the students. Also, once given insight into a set of science stories, students will have the opportunity to understand that nature of science is not the same as predesigned laboratory exercises. Through stories of science and experiences in enacting scientists, students are offered more possibilities to gain insight into the reality of the process of scientific practice. Many students find drama methods lively and stimulating and thus more memorable. They give a sense of the richness and complexity of the events they relate to, beyond that of simple textbook or other written accounts.

In addition, classroom dramas and theater-related activities are beneficial for focusing on the science in society perspective and socio-scientific issues in science education. Just as a well-known method in science is to make a simulation in the laboratory of a phenomenon in nature, so it is possible to simulate societal processes that relate to science, for instance, an international environmental conference, a consensus conference, or other democratic processes. The real world is brought into the classroom in the context of practical action. Divergent interests and ethical conflicts are essential to decision-making processes, as is also shown in all good plays and dramas. In role-play, the conflicts, combined with the personal relations the students develop to the issue, make them able to act. Students explore situations that create empathy and identification; thus, thoughts, knowledge, and feelings are stimulated and give room for action. Science is recontextualized to a situation where it has human scope and force. The cross-curricular potential in drama gives the opportunity for a style of learning that does not break knowledge and skills into artificial units, but permits exploration of the world using whatever medium is appropriate.

Aspects of Theater and Drama Activities

Dramatic activity may vary and take many different forms in the classroom. The drama may be structured in a way where students enact pre-prepared roles within a known framework of, for instance, scientific theories (e.g., playing electrons), or the dramatic activity may be impulsive, creating the moment, as it were; students have to improvise who they are and what to say. At any point along this continuum, a drama can be more or less spontaneous. An intermediate form could be an improvised role-play with a structured frame (e.g., role cards that describe the participating roles).

Another continuous variable is the degree of teacher involvement, that is, whether it is the teacher that impels the drama or the students. A group of students who create their own model of a scientific concept are together reconstructing knowledge so as to enhance their conceptual understanding. In order to guide the students, it may sometimes be necessary for the teacher to provide scaffolds in complicated scientific matters.

Dramas may also be characterized according to whether they are presentational or experiential. Presentational dramas have a major emphasis on communicating something to others outside the drama (e.g., the teacher, peers, or parents). They can be seen as plays with many theatrical features. When a small group of students dramatize a scientific concept (e.g., make a "meiosis ballet"), the intention is often communication to others. Another option is that students watch a play performed by others who, for instance, want to communicate issues involving science or scientists' work. This may give students a common experience to reference when, in this case, trying to understand nature of science. The experiential dramas, however, have focus on attempting to *live through* some aspect of an experience and exploring an opinion or attitude (e.g., a role-play with role cards about ethical issues in biotechnology). However, the division is not clear. When students themselves make a presentational drama of a scientific issue, it can be seen as an inquiry process, where imagination and creativity play a crucial role in making representations of science concepts. Thus, through the presentational drama, students may experience insights that deepen their understanding of scientific issues, giving the drama experiential facets.

Cross-References

- ▶ Critical Issues-Based Exhibitions
- ▶ Role-Plays and Drama in Science Learning
- ▶ Science Museum Outreach

References

Ødegaard M (2001) The drama of science education. How public understanding of biotechnology and drama as a learning activity may enhance a critical and inclusive science education. Dr. scient dissertation, University of Oslo. http://wo.uio.no/as/WebObjects/theses.woa/wa/these?WORKID=51609

Ødegaard M (2003) Dramatic science. A critical review of drama in science education. Stud Sci Educ 39(1):75–101

Science Tourism

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Science tourism is travel outside one's usual environment to learn about or participate in science. It includes specific types of tourism that are motivated by an interest in science, visitation of attractions that present science, travel to sites or events of scientific significance, science volunteer tourism, and school science field trips.

Many different types of tourism are **motivated by an interest in science**. Nature-based tourism, which includes more specific subtypes such as ecotourism, geotourism, and wildlife tourism, relies on immersion in and interaction with nature. Nature-based tourism activities include hiking; bird watching; snorkeling; whale watching; stargazing; visiting geothermal sites, alpine areas, deserts, and rainforests; and a multitude of other activities, all of which provide important opportunities for science learning. Such experiences are often enhanced by the provision of environmental interpretation, which aims to communicate scientific concepts while also creating opportunities for visitors to understand, appreciate, and enjoy the natural environment. Interpretation might be delivered by signs, brochures, displays, park rangers, or tour guides and is specifically focused on the natural features or species that visitors can experience firsthand at the site visited. Nature-based tourism has an added advantage in that it provides a financial incentive for the conservation and sustainable management of natural resources. Other types of special interest tourism with a science focus are also emerging. For example, space tourism offers opportunities for recreational space travel that may involve not only learning science but also participating in research activities while in orbit. Another emerging form of tourism known as “last chance tourism” involves traveling to places that are threatened by environmental factors such as climate change or overpopulation, in order to experience and learn about these places before it is “too late.”

Tourist attractions that specifically present scientific information include zoos, aquaria, botanic gardens, planetariums, national parks, science centers, natural history museums, and space museums. Social history museums and art museums may also host special exhibitions that present science either as their main purpose or incidentally, e.g., the popular *Body Worlds* exhibitions, *Leonardo da Vinci* exhibitions, and *Titanic* exhibitions. Visits to historical sites provide opportunities for learning about archaeology, architecture, or the science of conserving or restoring artifacts. Scientific information is often presented and interpreted at sites of important engineering feats, such as bridges, tunnels, and dams. Even a visit to a theme park can be enhanced by a presentation of the principles of physics that underpin the operation of amusement rides.

Tourists increasingly search for unusual and unique experiences. These may include **travel to sites of scientific significance, travel to witness science phenomena, or travel to attend science events**. Examples of significant sites are the Galapagos Islands, where visitors can follow in the footsteps of Charles Darwin; the Kennedy Space Center, where visitors can take a tour of NASA’s launch sites and even view a launch; and the European Organization for Nuclear Research (CERN), where visitors can learn about the fundamental research done at the world’s largest particle physics laboratory. Tourists also seek out the former homes of, burial sites of, or memorials dedicated to famous scientists, such as Isaac Newton, Marie Curie, Nikola Tesla, Albert Einstein, and Alan Turing. Science tourists may visit astronomical events such as eclipses, transits, or aurora that can only be viewed from particular locations; biological events such as coral spawning; or unique geological or geothermal phenomena such as unusual rock formations, glaciers, volcanoes, or geysers. Science events such as science festivals, conferences, and climate summits attract both scientists and hobbyists from around the world.

Science tourists can **volunteer to join a research expedition**, such as those organized by the Earthwatch Institute, where they can work on projects in wildlife conservation, rainforest ecology, marine science, and archaeology. This provides both a source of funding and practical assistance to scientists in collecting field data.

Finally, when school groups take **field trips** for the purpose of learning science, they also are participating in science tourism. Engaging in hands-on learning in real-life contexts enhances student motivation and increases the likelihood that science learning will be transferred to situations that students encounter outside of the school environment.

Increasingly, tourists seek travel experiences that engage them intellectually and develop their breadth and depth of general knowledge and understanding of the world. Travel offers many such opportunities for experiential learning in unique and unusual contexts which are likely to be both memorable and deeply rewarding for participants. Science tourism is thus an effective and increasingly important contributor to the lifelong learning of science in out-of-school contexts.

Cross-References

- ▶ Interpretive Centers
- ▶ Learning Science in Informal Contexts
- ▶ Out-of-school Science

Science, Technology and Society (STS)

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Keywords

Context

Introduction

Over the years, a range of factors including increased attention towards science and social responsibility, the prevalence of socio-scientific issues such as genetic engineering and nuclear power, a desire to humanize science, decreasing enrolment in physical sciences, and a surge of interest in the environment, have provided a fertile ground from which Science Technology Society and Environment (STSE) education has emerged. Originally, this movement began as Science Technology and Society (STS) education and then later evolved to include the environment (STSE). In this entry, we use STSE throughout, understanding that its roots are STS.

At a macro level, STSE education examines the interface between science and the social world. It is an umbrella term that supports a vast array of different types of theorizing about the connections between science, technology, society, and environment, and places science squarely within social, technological, cultural, ethical, and political contexts. At a micro level, STSE education includes decision-making, the coupling of science and values, integration (with other subject areas), nature of science (NOS) perspectives, and action. For many, STSE represents a shift from the status quo, a post-positivist vision for science education that emphasizes a *science for all* philosophy. What is clear is that there is no single, widely accepted view of STSE education. STSE in theory and practice emerges from different places for different people, influenced by particular contexts and circumstances and used for different purposes.

One of the earliest mentions of STSE appears in an article written by Jim Gallagher (1971) in *Science Education*. He argued strongly for a broader model of science teaching that included understanding the conceptual and process dimensions of science, as well their relationships to technology and society. Joan Solomon’s and Glen Aikenhead’s work (see, e.g., Solomon and Aikenhead 1994) did much to bring STSE to the fore. A range of significant texts during the 1980s and 1990s marked an ongoing commitment to STSE education and a collective desire for fundamental change in school science. Today, this desire for change in school science continues. For many jurisdictions STSE has become an important part of school science curriculum and the student experience.

Structure of the Field (STSE Theoretical Frameworks)

From what has gone before, it is clear that STSE is a complex construct. Other than a few broad principles, it is difficult to define what exactly constitutes STSE education. Indeed widely differing discourses have led to an array of distinct approaches, programs, and methods. To a great extent this is simultaneously the strength and weakness of the STSE movement. Despite this fluidity, over the years several have tried to develop classifications or typologies to pinpoint a structure for STSE and guide its further development, particularly its implementation in classrooms. However, it is important to note that these various schemas are not easily comparable. In particular no one is more comprehensive or more correct than the others. Rather the various efforts provide insight into different dimensions of the topic.

Ziman (1994), one of the earliest advocates of STSE, provides a general conceptual framework, useful for locating STSE and supportive of a multiplicity of approaches for its implementation. According to Ziman (1994), STSE contains philosophical, sociological, and historical dimensions, which in themselves can serve as approaches for implementation. Additionally, he proposes that STSE contains other ideological dimensions suggestive of other approaches, for example, utilitarian (vocational, relevance), transdisciplinary, and problem-based approaches. While Ziman's work is mostly philosophical and theoretical in nature, Aikenhead (1994), on the other hand, has written extensively about the spectrum of meanings and degrees of STSE inclusion found in existing science courses and programs. He captures the relative importance afforded to STSE by analyzing content structures and methods of student evaluation within a wide variety of science courses. Aikenhead's classification consists of eight categories that represent a spectrum. At one end (category one), STSE content is given the lowest priority compared to traditional science content, while at the other end (category eight), it is given highest priority. The eight categories are as follows: (1) motivation by STSE content, (2) casual infusion of STSE content, (3) purposeful infusion of STSE content, (4) singular discipline through STSE content, (5) science through STSE content, (6) science along with STSE content, (7) infusion of science into STSE content, and (8) STSE content. It is important to note that this scheme does not attempt to link STSE to any particular set of educational goals or priorities nor does it address specific teaching methods. In other words, Aikenhead's work describes *how* STSE might be integrated into the science curricula, but not the *why* and *what* of STSE education.

Pedretti and Nazir (2011) provide a classification that tackles these latter aspects. They provide a typology of possibilities for STSE education or what they call "currents" through consideration of the overall aims of science education, perspectives from the psychology of education, and examples of strategies or pedagogy for science programs. Within their typology, they identify and explore six currents in STSE education: (1) application/design, (2) historical, (3) logical reasoning, (4) value centered, (5) sociocultural, and (6) socio-ecojustice. They characterize the sociocultural current, for example, as promoting an understanding of science and technology within a broader sociocultural context, while engaging in an analyses of the complex social structures within which science operates. They link this current to the overall aim of teaching science as an important cultural and intellectual achievement and identify its dominant approaches as holistic, reflexive, experiential, and affective. Examples of pedagogical strategies include the use of case studies, storytelling, and integrated curricula. While Pedretti and Nazir are careful to caution that their classification is not exhaustive and that no current is "better" than the other, they suggest that their typology can be used by educators for critical analysis of the various discourses and practices within STSE, as it exists today.

Challenges to STSE Education

STSE programs and themes have been developed worldwide, at the elementary, secondary, and tertiary levels. In general, programs have been designed in an effort to interpret science and technology as complex socially embedded enterprises and to promote the development of a critical, scientifically and technologically literate, citizenry capable of understanding STSE issues, empowered to make informed and responsible decisions, and able to act upon those decisions. In Canada, for example, several provinces have continued to emphasize STSE as an important part of school science and retain it as an integral and primary focus of K-12 science curricula.

Although (STSE) education has gained considerable force in the past few years, it has made fewer strides in practice. An emphasis on STSE education presents challenges for educators – both practical and ideological in nature. Many have written about the practical challenges inherent to adopting an STSE approach. Practical challenges and barriers include the following: lack of time and resources, assessment issues, lack of professional development opportunities in STSE, and issues related to teacher confidence. Many fear that extensive coverage of socio-scientific subject matter devalues the curriculum and may alienate some science students. Furthermore, STSE instructional strategies often include, for example, town halls, debates, and role-plays. These activities (with their focus on decision-making, ethics, action, transformation, and empowerment) are not traditionally part of science teachers' repertoires.

Fewer, however, have written about the ideological bents and assumptions that underpin different formulations of science education in general and STSE education in particular. For example, a view that science education should be focused on teaching science content (a predominantly transmissive view) rather than focused on social reconstruction and change (a transformative view) can produce radically different experiences and challenges in the science classroom. For example, coupling science and values education can be problematic for some. How do educators reconcile teaching about science and values? How does a teacher position himself/herself? How do teachers address personal values in the classroom and accommodate diverse views, cultural contexts, and ways of thinking about the world? Action and the politicization of science present another set of problems. The notion of a sociopolitical science curriculum that promotes social justice and transformation provides a very different vision of science teaching and science education, and for some, this can be disconcerting. Such competing ideologies represent a major shift in the way that science education and therefore science teaching are conceptualized and may challenge science teachers' professional identities. These practical and ideological challenges provide rich avenues for future research in STSE education that is rooted in classroom praxis, pedagogy, teacher professional development, and student learning.

STSE and Other Related Movements

STSE has evolved to include other movements and manifestations. In Pedretti and Nazir's (2011) mapping of the field, they use the metaphor of currents to describe the evolution of STSE over time. According to them, STSE education is comparable to a vast ocean of ideas, principles, and practices that overlap and intermingle one into the other. At any one time the field has been characterized by certain ideas coming together to form discernible currents. These currents are constantly changing and shifting according to the context in which they occur. It can be argued that new and emerging currents remain within the STSE fold because they share a similar post-positivist view of science and science education discussed earlier on.

Two currents or movements that have evolved over time and which are particularly strong today are socio-scientific issues (SSI), based on the work of Dana Zeidler and his colleagues, and environmental education (EE). It can be argued that SSI and EE share similar principles, visions, and pedagogies as STSE education (although proponents of these movements may argue differently). The SSI movement pays particular attention to the ethical aspects contained within socio-scientific issues. It focuses on the moral and character development of students. Zeidler's work takes a justice-based, cognitive moral developmental approach to science education. He proposes the use of carefully selected problems from the domain of science to stimulate moral deliberation and consequently moral development in science classes. The SSI model is fortuitously supported today by a resurgence of interest in values education worldwide. Environmental education is another strong current within STSE today. EE, in general, has been gaining momentum worldwide, as the idea of humankind's negative impact on the environment and the consequences for the continued existence of all life on the planet becomes increasingly accepted. STSE has always shared many of the philosophical and educational ideas underpinning the ecojustice movement. In particular, EE derived from an STSE base tends to emphasize the economic and sociopolitical aspects of environmental problems and the need to provide people with the tools (skills, knowledge, and dispositions) to actively transform society. Citizenship that promotes civic responsibility (to humans and non-humans), agency, and emancipation are key features of this current.

In conclusion, STSE education situates science in a rich and complex tapestry – drawing from politics, history, ethics, and philosophy. Although a challenge politically, ideologically, and practically, STSE presents an opportunity to learn, view, and analyze science in a broader context while recognizing the diversity of needs of students and classrooms. STSE, in its many forms and currents, brings relevancy, interest, and real-world connections to the science classroom.

Cross-References

- ► Environmental Education
- ► Science and Social Responsibility
- ► Socioscientific Issues

References

Aikenhead G (1994) What is STS teaching? In: Solomon J, Aikenhead G (eds) STS education: international perspectives on reform. Teachers College Press, New York, pp 47–59

Gallagher JJ (1971) A broader base for science teaching. Sci Educ 55(3):329–338

Pedretti E, Nazir J (2011) Currents in STSE education: mapping a complex field, 40 years on. Sci Educ 95(4):601–626

Solomon J, Aikenhead G (eds) (1994) STS education: international perspectives on reform. Teachers College Press, New York

Ziman J (1994) The rationale for STS is in the approach. In: Solomon J, Aikenhead G (eds) STS education: international perspectives on reform. Teachers College Press, New York, pp 21–31

Science, Technology, and Engineering Interrelationships: Assessment of the Understanding of

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Keywords

Assessment; Engineering; Interrelationships; Science; Technology

In most reports setting forth frameworks or standards for science, technology, and engineering, the three domains are described as related by their focus on systems in the real world yet different in the roles that the disciplines play in understanding and modifying the world. The definitions for this entry are based on documents produced by national sets of experts in which the relationships of science, technology, and engineering are described. Definitions of science, engineering, and technology can be culled from these frameworks and standards developed by engineering and science organizations, as well as from standards for engineering and technology for state, national, and international assessments.

These definitions of science, technology, and engineering are the starting points for developing assessments of understanding of the ways in which they are related. This entry begins with a summary of prominent conceptualizations of science, technology, and engineering. The definitions are followed by descriptions of an assessment framework that can be used to select or develop and assessments of understanding the similarities and differences of science, technology, and engineering. Descriptions of some potential types of assessment tasks and items to test understanding of the interrelationships of science, technology, and engineering are provided.

Definitions of Science, Engineering, and Technology

Science refers to understanding and studying phenomena in the natural world, while engineering and technology are applications of science to create the human-made world. Engineering is defined as a systematic and iterative approach to designing objects, processes, and systems to meet human needs and wants. Technology is defined as any modification of the natural or designed world developed to fulfill human needs or desires. Technologies, therefore, are products and processes resulting from application of engineering design processes. Technologies also often function as tools and processes used to support engineering design.

Sources of Conceptualizations of Science, Technology, and Engineering

Framework for K-12 Science Education and the Draft Next Generation Science Standards

The framework provides a broad description of the content and sequence of learning in science and engineering expected of all students by the end of high school. Science disciplinary core ideas, crosscutting concepts important in all disciplines, and practices describing the ways scientists and engineers work are presented. Engineering and technology are included as applications of science. Core ideas are specified for physical, life, and earth and space sciences and for engineering and technology. These key disciplinary areas are integrated with foundational crosscutting concepts such as cause and effect, systems and models, and patterns. The science and engineering practices include skills for asking questions and defining problems, developing and using models, planning and carrying out scientific investigations, analyzing and interpreting data, and using mathematics and computational thinking.

Engineering is used to mean engagement in a systematic design practice to achieve solutions to particular human problems. Technology is used to include all types of human-made systems and processes. Two core engineering ideas are specified. The first is engineering design – how engineers solve problems. The second core idea is understanding of the links among engineering, technology, science, and society. Engineering design is subdivided into three components: (1) defining and delimiting a problem, (2) developing possible solutions, and (3) optimizing the design solution. Links among engineering, technology, science, and society are partitioned into (1) interdependence of science, engineering, and technology and (2) the influence of engineering, technology, and science on society and the natural world. The framework describes grade band end points for each of the three components.

The draft Next Generation Science Standards provides more specific guidance for assessing scientific ideas and engineering design that produces and uses technology. For example, performance expectations have been developed that integrate the engineering core ideas with crosscutting concepts, such as systems and models and cause and effect, and also with science and engineer practices.

Technology and Engineering Literacy (TEL) Framework for the 2014 National Assessment of Educational Progress

TEL framework is unique in its focus on assessing the interrelationships of engineering and technology. In the framework, technology and engineering literacy is defined as the capacity to understand technology and engineering design principles and to use and evaluate engineering design processes (NAGB 2010). Technology and engineering literacy is divided into three assessment areas, design and systems, information and communication technology, and technology and society. Within design and systems, three subareas of essential knowledge and skills were identified: nature of technology, engineering design, system thinking, and maintenance and troubleshooting.

Principles for the nature of technology expand the scope of common conceptualizations of technology beyond computers and the Internet. The broader view includes every way people manipulate the natural environment to satisfy needs and wants. Therefore, technology includes all the various devices and systems that people make to fulfill some function. The framework lays out key principles for the nature of technology: (1) technology is constrained by the laws of nature; (2) scientists examine what exists in nature, and engineers modify natural materials to meet human needs and wants; (3) technological development involves creative thinking; (4) technologies developed for one purpose may be adapted for other purposes; (5) science, technology, engineering, and mathematics and other disciplines are naturally supportive; (6) the pace of technological change has been increasing; and (7) tools help people to do things efficiently, accurately, and safely. The framework then lays out assessment targets for grades 4, 8, and 12.

The engineering design subarea in the TEL framework is described as an iterative, systematic process for solving problems. The process begins with stating a need or want and the criteria and constraints of the challenge. Then potential solutions are explored referencing relevant scientific and technical information. Potential solutions are compared, and models and prototypes are constructed, tested, and evaluated to see how they meet the criteria and constraints of the problem. The results of the engineering design process will be technology in the form of either a product or a process. The framework specifies key principles of engineering design and proposes assessment targets for grades 4, 8, and 12. Two additional components of design and systems are systems thinking and maintenance and troubleshooting. For each component, principles are identified and assessment targets for grades 4, 8, and 12 are presented.

The framework also specifies components, principles, and assessment targets for grades 4, 8, and 12 for the prominent technology area of information and communication technology (ICT). ICT is presented as a separate assessment area within technology and engineering literacy because of the central place ICT plays in learning and functioning in school, the workplace, and daily living. ICT subareas to assess include understanding and use of technologies for (1) construction and exchange of ideas and solutions, (2) information research, (3) investigation of problems, (4) acknowledgment of ideas and information, and (5) selection and use of digital tools.

Each of the frameworks and standards described above can serve as resources for specifying the interrelationships of science, technology, and engineering to be assessed.

Evidence-Centered Assessment Design

The focus of this entry is on methods for assessing understanding of the interrelationships among science, technology, and engineering. The selection or development of assessments will depend on the purposes of the assessments and the interpretations of the data. An assessment may be intended to provide diagnostic feedback and be used in a formative way to allow adjustments during instruction to improve performance. An assessment may be intended to serve a summative purpose to report on the status of proficiency at a point in time. These purposes will have implications for the criteria used to select, design, or interpret assessments.

A useful framework for understanding the structure of assessments is evidence-centered assessment design (Mislevy et al. 2004). Evidence-centered design is intended to structure an assessment argument. The argument begins with the claim that specified knowledge or skills have been learned. Evidence to support the claim comes from the types of questions or tasks that will elicit observations and performances of the targeted knowledge or skill. Summaries of performances, typically in the form of scores to be reported and interpreted, then complete the argument. Evidence-centered assessment design tightly links the targeted knowledge and skills (student model), with assessment tasks and items to elicit evidence of these targets (task models), with specifications of how the evidence will be scored and analyzed to report proficiencies (evidence model). The evidence-centered design framework can be used to analyze and evaluate existing assessments or to guide the systematic development of new ones.

The essential first step in assessing student understanding of the interrelationships of science, technology, and engineering will be to settle on the definitions of science, technology, and engineering and to specify the similarities, differences, and roles to be tested. The features and functions would become the first component of the student model. A second component of the student model would be the cognitive demands or levels of reasoning required. Cognitive demands could range from identifying definitions and lists of similar and different features to analyzing the roles of science, technology, and engineering in scenarios; to actually applying ideas and practices in relevant problems involving the use of science, engineering, and technology; and to evaluating others' applications of science, technology, and engineering in a range of scenarios.

The engineering design process creates plans for developing solutions. Solutions may be tangible artifacts or technologies, such as digital devices or farm machinery. Solutions may rely on scientific knowledge and new or improved technological processes such as more efficient manufacturing procedures or pharmaceutical clinical trials. These solutions are technologies that have been developed to address needs in areas of the designed world such as medicine, agriculture, energy, transportation, manufacturing, and construction. Students tend to think of technology in terms of computers and digital technologies, not in terms of the artifacts and solutions engineered in the many other areas of the designed world. Students are expected to understand that there are technologies in all these areas, from pills, plows, plugs, planes, and pinions to pickup trucks. Specifications of the knowledge to be tested will need to decide what students need to understand about the distinctions and overlaps among science, technology, and engineering. It is likely that such discriminations would be part of a more comprehensive assessment of scientific, engineering, and technology problems and contexts in which they occur. Therefore, statements of what the student needs to know and the level of reasoning for showing it will become the assessment targets of the student model.

In evidence-centered assessment design, the task model specifies the kinds of contexts, problems, and items that would elicit evidence that the students understood the relationships of science, technology, and engineering. Simple items could list features of scientific ideas and practices, engineering design processes, and technologies and have students select examples of their appropriate use to given problems. Descriptions of needs addressed by an engineering project that is producing solutions could include questions to determine that students understood about the role of scientific knowledge contributing to the solutions and whether new tools or new processes are technologies. Tasks and items could be designed around scenarios presenting scientific questions and engineering design problems in a range of applied contexts. An overarching problem could be to select scientific knowledge, technologies, and engineering processes to use in attempting to solve the problem or to critique descriptions of their appropriate use in scenarios.

The SimScientists program has developed simulations to assess understanding and use of science and engineering practices for a number of science systems (Quellmalz et al. 2012b; http://simscientists.org). As shown in Fig. 1, a scenario was developed in which students are working to establish a sustainable research center in Antarctica. By harnessing available sunlight and wind, scientists at the station are able to generate electricity, which can be used for the electrolysis of water, which in turn results in the production of hydrogen gas. The simulation-based assessments have been designed to assess core ideas about atoms and molecules, changes in state, properties of matter, and the science practices of designing and conducting investigations. The scenario could be augmented with sets of tasks about the design, testing, and troubleshooting for an energy production, conversion, and

The research center uses wind and sunshine to generate electricity. You can use the electricity to create hydrogen without producing any pollution!

Now that you have a way to generate hydrogen gas, your next task is to find out how to use hydrogen for cooking.

Trial	Add Oxygen	Add Nitrogen	Add Spark
1	✓		
2		✓	
3	✓		✓
4		✓	✓
5	✓	✓	✓

You need to know what conditions caused a reaction in the flask. You will need to answer the following questions about hydrogen gas.

Does hydrogen react with oxygen if there is a spark?
Does hydrogen react with oxygen whenever they are mixed?
Does hydrogen react with nitrogen if there is a spark?
Does hydrogen react with nitrogen whenever they are mixed?

Review your trials and decide if you have enough information to answer the questions to the left.

- If you want to review one of your trials, click the VIEW button for that trial.
- You can then click RESET to start that trial again.
- If you need to run another trial, click NEW TRIAL.
- When you are satisfied with your trials, click NEXT.

Science, Technology, and Engineering Interrelationships: Assessment of the Understanding of, Fig. 1 SimScientists simulation-based assessment

storage system that contributes to a sustainable research center.

As foundational computer models of such systems, natural and man-made, are developed, they can support the development of tasks to assess science, technology, and engineering concepts and practices and also to assess twenty-first-century skills such as communication and collaboration (Quellmalz et al. 2012a). For example, students could be asked to construct descriptions for the Antarctic Research Center Board for a proposed sustainable energy plan or to critique if solutions proposed by others meet the design constraints. A virtual collaborator could be queried to seek relevant information about the trade-offs of alternative sustainable energy treatments.

The assessment evidence model would involve determining what kind of scoring and reporting would convey that the student understands the similarities and differences and roles of the three areas. Specific reports about progress and proficiency on the assessment targets would be needed.

The assessment selection or development can use the framework of evidence-centered assessment design to guide analyses of existing tasks and items or to guide the development of appropriate tasks and items. The framework would ask if the knowledge to be tested is clearly specified (student model) and if the tasks and items will provide evidence if the knowledge and practices have been applied in a range of areas such agriculture, medicine, and manufacturing. The framework would also ask if the scoring and reporting clearly allowed decisions to be made about whether the understanding of the interrelationships of science, technology, and engineering is sufficiently strong. The decisions could then be used diagnostically to inform further instruction or to inform a proficiency report. The key to sound assessment is that the assessment argument is clear and supported.

Cross-References

- ▶ Assessment of Knowing Engineering and Technology and Doing Engineering and Technology: Overview
- ▶ Engineering Design, Assessing Practices of
- ▶ Technology, Assessing Understanding of

References

Achieve (2012) Next generation science standards. http://www.nextgenscience.org/nnext-generation-science-standards

Mislevy RJ, Almond RG, Lukas JF (2003) A brief introduction to evidence-centered design. Educational Testing Service, Princeton

National Assessment Governing Board (NAGB) (2008) Technology and engineering literacy framework for the 2014 national assessment of educational progress. National Assessment Governing Board, Washington, DC

National Research Council (NRC) (2011) A framework for K-12 science education: practices, crosscutting concepts, and core ideas. The National Academies Press, Washington, DC

Quellmalz ES, Timms MJ, Buckley BC, Davenport J, Loveland M, Silberglitt MD (2012a) 21st century dynamic assessment. In: Mayrath M, Clarke-Midura J, Robinson DH (eds) Technology-based assessments for 21st century skills: theoretical and practical implications from modern research. Information Age, Charlotte

Quellmalz ES, Timms MJ, Silberglitt MD, Buckley BC (2012b) Science assessments for all: integrating science simulations into balanced state science assessment systems. J Res Sci Teach 49(3):363–393

Science, Technology, Engineering, and Maths (STEM)

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Keywords

Engineering; Technology

Historical Foundations

Historically, science had a place in education before the time of Plato and Aristotle (e.g., Stonehenge). Technology gradually increased since early human inventions (e.g., indigenous tools and weapons), rose up dramatically through the industrial revolution and escalated exponentially during the twentieth and twenty-first centuries, particularly with the advent of the Internet. Engineering accomplishments were evident in the constructs of early civil works, including roads and structural feats such as the Egyptian pyramids. Mathematics was not as clearly defined BC (Seeds 2010), but was utilized for more than two millennia (e.g., Archimedes, Kepler, and Newton) and paved its way into education as an essential scientific tool and a way of discovering new possibilities. Hence, combining science, technology, engineering, and mathematics (STEM) areas should not come as a surprise but rather as a unique way of packaging what has been around for centuries. For education, the acronym STEM has emerged to initiate innovations in curriculum design and practices mainly towards facilitating career choices in these much needed fields.

What Is STEM?

STEM education is an opportunity to develop competencies in high-demand fields. Engineering education has not been included traditionally in school education; however, its inclusion presents hands-on problem-based activities for fusing science, technology, and mathematics to engage students in engineering innovations. The scientific and mathematical undertakings towards devising technology with the assistance of Internet information and communication have facilitated engineering advancements across a range of fields (e.g., chemical, structural, mechanical, civil, software). The abundance of engineering positions and scope for increased developments has lead towards engineering education beginning earlier within school systems (e.g., primary and middle schools).

Various countries are positioned to promote STEM education. In 2008, the US government commissioned reports on how to transform STEM into implementable educational programs and, early in 2010, President Obama committed $3.7 billion for STEM education in his 2011 budget (National Institutes of Health 2010). Malaysia, as another example, up to 2012 had outlaid significant funds for up-skilling STEM teachers across their country, particularly with the uptake of degrees from outside providers, and the UK is establishing national STEM education networks (e.g., see http://www.dcsf.gov.uk/stem/). There are STEM education initiatives in Australia, for instance, the Department of Education, Science, and Training (DEST) supported financially 355 projects conducted between 2005 and 2007, out of which 83 projects combined the STEM areas (see http://www.asistm.edu.au/asistm/). Although these initiatives were largely isolated occurrences involving pockets of partnerships that did not appear to have significant impact on schools outside the original arrangements, they commenced a process towards forming a national STEM agenda.

STEM Education

In a resource-driven world, university enrolments in STEM areas have not met career demands, which is a rationale for profiling STEM education. Importantly to the STEM agenda is the focus on females, as they are largely underrepresented in STEM at the university level. For example, in 2012 there were only 11–15 % undergraduate enrolments in engineering across Australian universities with the 2009 Melbourne Declaration advocating a STEM education agenda by building the capacity of STEM teachers. Part of the reason for low female involvement in STEM fields lies in stereotyping female competencies; hence, there are calls for establishing a gender equity curriculum for STEM education to overturn stereotypical views, especially during the early years of education and into the STEM workforce. Furthermore, the underrepresentation of females in STEM areas has driven researchers to explore ways to uncover how to engage and motivate females into these fields. Websites have been launched to address the gender gap in STEM areas such as engineering (http://www.engineergirl.org/), which in particular aims at educating middle-school females. For both genders, educational advancements must include hands-on activities that aim to increase students' confidence and interests in STEM.

Ongoing STEM development

Further developments in STEM education are needed to initiate, promote, and sustain its theoretical structure in education, some of which can include establishing STEM education forums. For instance, the first international STEM in Education conference in 2010 (http://stem.ed.qut.edu.au/) provided a platform for educators to share knowledge in and across their respective disciplines. The conference moves around internationally (e.g., Beijing Normal University, 2012 and University of British Columbia, 2014) to engage educational communities in the STEM education fields. Indeed, other STEM conferences (e.g., www.genderandSTEM.com and the UK STEM Annual Conference) are sprouting up around the world to facilitate conversations on relevant STEM topics. STEM education holds promise for educating current youth into high-demand STEM careers emanating from a worldwide growth in developing and manipulating resources.

Cross-References

▶ Science, Technology and Society (STS)

References

National Institutes of Health (2010) National institutes of health: summary of the FY 2011 president's budget. http://officeofbudget.od.nih.gov/pdfs/FY11/Summary%20of%20the%20FY%202011%20Presidents%20Budget.pdf. Accessed 15 May 2012

Seeds MA (2010) Foundations of astronomy. Thomson, Belmont

Science-Themed Fiction

▶ Science Fiction

Scientific Language

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Keywords

Argumentation; Interpretive system; Language; Meaning-making; Metaphor; Science

There is nowadays extended consensus around the recognition that scientific knowledge is "dependent inextricably on language and language is also central to our ability to think [scientifically]" (Evagorou and Osborne 2010, p. 136). Language thus becomes a key element in science education: it is a tool that allows us to understand the natural world, to express our ideas on it, and to develop scientific knowledge. This paramount role of language in supporting science learning processes was acknowledged at least five decades ago, notably through the seminal work of Jerome Bruner; such acknowledgment can be attributed – at least partially – to the dissemination of Lev Vygotsky's ideas in English. However, it was not until the 1980s, and following developments in the philosophy of science and in educational studies, that science education research began to pay attention to the linguistic aspects inherent to science teaching. As a consequence of this new focus, in the last two decades, a thriving research line has emerged, with several theoretical perspectives that focus on different aspects of the issue of scientific language in the classroom (e.g., Sutton 1996; Lemke 1990; Sanmartí et al. 1999).

Sutton (1996), in his now classic paper *Beliefs about science and beliefs about language*, portrays two distinct epistemic functions of language in science: language can serve *as a labeling system*, to tag and transmit established pieces of knowledge, or *as an interpretive system*, actively used to generate and consolidate new understandings. In that text, Sutton is advocating for shifting from the positivistic emphasis on language as a means of conveying conceptual information toward the constructivist idea of understanding language as a way of meaning-making.

Adhering to such characterization of scientific language for the science classes would import the need to introduce students simultaneously in the patterns of reasoning and the patterns of language that are developed in the context of doing science. Along this line, Evagorou and Osborne (2010, p. 138) claim:

> [B]ecause reading and writing are activities that are constitutive of science, and because the language of science is complex and foreign to many students, we see teaching science as fundamentally a process of teaching a language – one in which the teacher has both to help students to interpret and construct meaning from scientific text and one in which they must provide opportunities to develop their fluency and capabilities with that language. In the classroom, three main forms of language are used as tools for understanding, communicating, and developing knowledge: talk, writing and reading.

In the same spirit of the previous paragraph, Lemke (2001) argues that we could understand science education as a "second socialization": an enculturation into a subcommunity – science – that has its own representations, methods, ethos, and jargons. This theoretical approach should motivate us to examine how people learn to talk and write the language of science while engaging in specific scientific activities, such as observing, experimenting, debating, or publishing. In his well-known book *Talking Science*, Lemke (1990) equates science learning, at least partially, to learning to "talk science." This implies moving away from science lessons dominated by a "triadic dialogue" centered on teachers' talk – as in the classical IRF (initiation-response-feedback) sequences. Here, Lemke introduces a very suggestive idea: talking science could be considered a very elaborate social process, modeled on the metaphor that science is a foreign language that students have to learn.

In his own words:

> Learning science means learning to *talk* science. It also means learning to use this specialized conceptual language in reading and writing, in reasoning and problem solving, in guiding practical action in the laboratory and in daily life. It means learning to communicate in the language of science and act as a member of the community of people who do so. "Talking science" means observing, describing, comparing, classifying, analyzing, discussing, hypothesizing, theorizing, questioning, challenging, arguing, designing experiments, following procedures, judging, evaluating, deciding, concluding, generalizing, reporting, writing, lecturing, teaching in and through the language of science. (Lemke 1990, p. 1)

Lemke concludes that we learn to speak the language of science in much the same way in which we learn any other language: practicing it with people who master it and using it in a variety of pragmatic communicational situations, where it should be employed in its most frequent typologies, genres, and text formats.

In accordance with this theoretical perspective, students must not only understand the main concepts implicated in the theories and models and grasp the scientific vocabulary, they also have to be able to apply the necessary language structures and patterns and use the correct discursive tools and rhetorical strategies. Consequently, they must be able to distinguish and make use of the different genres of science, such as descriptions, definitions, explanations, and argumentations. Specifically related with the use of the scientific vocabulary, there is a crucial point about the meanings of words: science teachers should make bridges between the everyday meanings of terms and their meaning in specific scientific contexts. This requires acknowledging that scientists use language in very special, highly stylized ways:

> Not only is there a specialist scientific vocabulary consisting of words which are recognizably unfamiliar but there are familiar words such as 'energy', 'power' and 'force' which must acquire new meanings. Moreover, the charts, symbols, diagrams and mathematics that science deploys to convey ideas, are essential to communicating meaning and students must learn to both recognize and understand their use. The challenge for the teacher then is to introduce and explain this new vocabulary; the challenge for the student is to construct new meanings from such a language. (Evagorou and Osborne 2010, p. 136)

There are a lot of unobservable entities that science teachers have to teach in the classroom, for example, cells or electric current. The teaching of such entities depends on the use of robust representations: a cell is represented as a brick, electric current is referred to in terms of water flow, and particles are depicted as balls. All of these are metaphors, i.e., *transferences* of meaning. According to the philosopher of science Rom Harré, through this metaphorical mechanism, new vocabulary can be created within the existing structure of any given language; this process secures the intelligibility of the term in the new context of use.

Analogies and metaphors are utilized to construct and scaffold students' understandings. They are also essential components of theories and allow the generation of mental models. Such models serve the purpose of providing plausible descriptions, explanations, and predictions about real systems in nature. Based on models, students can build a special kind of evidence-based explanation to give sense to the world around them; this kind of explanation is *argumentation*:

> Work in the specialized argumentative practices of the various disciplines suggests that students not only need to write in order to master the concepts and work of a field, but more particularly to develop competencies in the specific argumentative practices of their fields [. . .]. In addition to the genre-specific writing competencies, with associated argumentative patterns, students must begin to gain a feel for the argumentative forums and dynamics of their fields. They must learn the kinds of claims people make [and] what kind of evidence is needed to warrant arguments [. . .]. (Kelly and Bazerman 2003, pp. 29–30)

Kelly and Bazerman emphasize the importance of writing and talking in the language of the disciplines within the frame of ideas known as "writing across the curriculum" (WAC). They propose to engage students in instances in which they must produce arguments in the different disciplines and beyond them. From these arguments, students learn to talk and write the language of the different scholarly fields. In their framework, these authors indicate that argumentative discourse – that trying to persuade – would be one of the communicational functions that have played a significant role in the development of scientific knowledge, hence its importance in the learning of science.

Jiménez-Aleixandre and Erduran (2008, p. 4) also highlight the importance of scientific argumentation. This competence is

> instrumental in the generation of knowledge about the natural world [and] plays a central role in the building of explanations, models and theories [. . .] as scientists use arguments to relate the evidence they select to the claims they reach through use of warrants and backings. [. . .] [A]rgumentation is a critically important discourse process in science, and that it should be promoted in the science classroom.

They also propose that there are at least five intertwined dimensions or potential contributions from the introduction of argumentation in the science classrooms (cf. Jiménez-Aleixandre and Erduran 2008, p. 5):

- Supporting the access to the cognitive and metacognitive processes characterizing expert performance and enabling modeling for students. This dimension draws from the perspective of "situated cognition" and the consideration of science classes as communities of learners.

- Supporting the development of communicative competences and particularly critical thinking. This dimension draws from the theory of communicative action and the sociocultural perspective.
- Supporting the achievement of scientific literacy and the empowerment of students to talk and write the language of science. This dimension draws from language studies and social semiotics.
- Supporting the enculturation into the epistemic practices of the scientific culture and the development of epistemic criteria for knowledge evaluation. This dimension draws from science studies, particularly from the epistemology of science.
- Supporting the development of reasoning, particularly the choice of theories or positions based on rational criteria. This dimension draws from philosophy of science, as well as from developmental psychology.

At the same time, the Group LIEC (at the Universitat Autònoma de Barcelona in Spain) defines argumentation as a social, intellectual, and verbal activity used to support or rebut a claim; when arguing, in addition to the content of the claim, its purpose and recipients are important. In order to argue, one needs to choose between different options or explanations and to provide reasoned criteria to assess the most appropriate choices (Sanmartí 2003). In order to learn argumentative competences, Sanmartí proposes that it is necessary to promote explicit instances to teach school scientific argumentation. This means teaching what are the main traits and characteristics of this genre and practicing this skill in relation with school science content.

The research on scientific language in the classroom reviewed here has as unifying thread the hypothesis that through talking and writing science, students can access to new epistemic levels. In their school science "texts," students give meaning to the symbols, definitions, relations, and communicative patterns that support their use of scientific models. In turn, these texts produced in the science classes are a powerful tool for the (self-)assessment of learning.

Cross-References

- ▶ Argumentation
- ▶ Discourse in Science Learning
- ▶ Epistemic Goals
- ▶ Language and Learning Science
- ▶ Models

References

Evagorou M, Osborne J (2010) The role of language in the learning and teaching of science. In: Osborne J, Dillon J (eds) Good practice in science teaching: what research has to say, 2nd edn. Open University Press/McGraw-Hill, New York, pp 135–157
Jiménez-Aleixandre MP, Erduran S (2008) Argumentation in science education: an overview. In: Erduran S, Jiménez-Aleixandre MP (eds) Argumentation in science education: perspectives from classroom based research. Springer, Dordrecht, pp 3–27
Kelly G, Bazerman C (2003) How students argue scientific claims: a rhetorical-semantic analysis. Appl Linguis 24(1):28–55
Lemke JL (1990) Talking science: language, learning, and values. Ablex Publishing Corporation, Norwood
Lemke JL (2001) Articulating communities: sociocultural perspectives on science education. J Res Sci Teach 38(3):296–316
Sanmartí N, Izquierdo M, García P (1999) Hablar y escribir: Una condición necesaria para aprender ciencias. Infancia y Aprendizaje 281:54–58
Sanmartí N (ed) (2003) Aprendre ciències tot aprenent a escriure ciència. Edicions 62, Barcelona
Sutton C (1996) Beliefs about science and beliefs about language. Int J Sci Educ 18(1):1–18

Scientific Literacy

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Originating in the 1950s, the term "scientific literacy" has been used to express diverse goals ranging from a broad knowledge of science to a particular purpose of science education (Bybee 1997). In 1958, Paul DeHart Hurd provided a clear perspective when he described scientific literacy as an understanding of science and its applications to an individual's experience as a citizen. Hurd made clear connections to the science curriculum and the selection of instructional materials that provide students with the opportunities to use the methods of science; apply science to social, economic, political, and personal issues; and develop an appreciation of science as a human endeavor and intellectual achievement (Hurd 1958). Although there have been variations, Hurd's definition expresses the application of scientific knowledge to the situations individuals will encounter as citizens. This view differentiates scientific literacy from other goals of science education.

The general use of scientific literacy has the advantage of unifying the science education community by centering on what is perceived to be the primary goal. The disadvantage of using the term is the loss of its specific meaning which was an understanding of science and its applications to personal, national, and global perspectives.

In the year 2000, George DeBoer published a historical review of the term scientific literacy. There have been numerous different goals of science education, all related to scientific literacy. DeBoer suggested a broad conceptualization of scientific literacy, one allowing for variations in curriculum and instruction. The broad goal suggested by DeBoer is consistent with earlier definitions, namely, to enhance the public's understanding and appreciation of science. Here are critical insights about scientific literacy – it is about an adult population's level of understanding and appreciation of science, it changes with time, and school experiences certainly affect the public's attitudes toward science and their disposition to continue developing their understanding and appreciation of science (DeBoer 2000).

Across the decades, there has emerged a critical distinction, between an emphasis on education for future citizens and education for future scientists. In 2007, Douglas Roberts published a significant essay in *Handbook of Research on Science Education* (Abell and Lederman 2007). Roberts identifies a continuing political and intellectual tension with a long history in education. The two conflicting perspectives can be stated in a question – should curriculum emphasize subject matter itself, or should it emphasize the application of knowledge and abilities in life situations? Curriculum designed to answer the former, Roberts refers to as Vision I, and the latter he refers to as Vision II. Vision I looks within science disciplines: it is internal and foundational. Vision II uses external contexts that students are likely to encounter as citizens (Roberts 2007).

A significant contemporary issue for those developing standards, designing curriculum, and providing professional development is recognizing the difference between the two perspectives just described. One perspective centers on disciplines such as biology, chemistry, physics, or the Earth sciences. In this perspective, programs and teaching practices answer questions such as the following: What knowledge of science and its methods should students learn? What facts and concepts from science should be the basis for school programs? In contrast, there is a *contextualist* (Fensham 2009) perspective that will begin with situations that require an understanding and application of science. When thinking about standards, curriculum, and instruction from a contextualist view, questions center on the following: What science should students know, value, and be able to do as future citizens? What contexts could be the basis for science education? The difference between these two perspectives is significant because it has implications for curriculum emphasis, selection of instructional strategies, design of assessments, and professional education of teachers. The subsequent outcomes – what students learn about science, the attitudes they develop, the skills they acquire, and their ability to competently identify, analyze, assess, and respond to life situations – also differ significantly.

The Program for International Student Assessment (PISA), an initiative of the Paris-based Organization for Economic Cooperation and Development (OECD), reinforced the original perspectives of science literacy and Roberts' Vision II in the frameworks for 2006 and 2009 science assessments. The PISA Science assessments focused on scientific competencies that clarify what 15-year-old students know and are able to do within appropriate personal, social, and global contexts.

In PISA, scientific literacy referred to four interrelated features that involve an individual's:

- Scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomenon, to draw evidence-based conclusions about science-related issues
- Understanding of the characteristic features of science as a form of human knowledge and inquiry
- Awareness of how science and technology shape our material, intellectual, and cultural environments
- Willingness to engage in science-related issues, and with the ideas of science, as a constructive, concerned, and reflective citizen (OECD 2006, 2009)

PISA Science implemented the definition of *scientific literacy* and its science assessment questions using a framework with the following components: *scientific contexts* (i.e., life situations involving science and technology), the *scientific competencies* (i.e., identifying scientific issues, explaining phenomena scientifically, and using scientific evidence), the domains of *scientific knowledge* (i.e., students' understanding of scientific concepts as well as their understanding of the nature of science), and student *attitudes toward science* (i.e., interest in science, support for scientific inquiry, and responsibility toward resources and environments).

In conclusion, for many with responsibility for national standards, curriculum materials, and assessments, the distinction between two interpretations of science literacy – "Vision I" and "Vision II" – is blurred. The dominant perceptions about the content and learning outcomes are Vision I; the principal (sometimes exclusive) emphasis is on discipline-based science knowledge and methods. An often unstated assumption is that if students understand science concepts, they will apply that knowledge to the personal, social, and global problems they encounter as citizens. That assumption could certainly be questioned. For those interested in scientific literacy, school science programs should incorporate Vision II clearly, consistently, and continually. Students should have experiences where they confront appropriate socio-scientific issues and problems within meaningful contexts. PISA Science provided an assessment model and, through backward design, the basis for curriculum and instruction for this view of scientific literacy.

Here is an essential challenge for twenty-first-century science education. Most school programs emphasize fundamental knowledge and processes of the science disciplines. These science programs are intended implicitly to provide students with the foundation for professional careers as scientists and engineers. With the centrality of science and technology to contemporary life, full participation in society requires that all adults, including those aspiring to careers as scientists and engineers, be scientifically literate. That is, they not only develop understandings of science fundamentals, they learn how to apply that knowledge to life situations.

The level of a society's scientific literacy depends on citizens' understanding, receptivity, and appreciation of science as a human endeavor with significant influence on their lives and society.

Cross-References

- ▶ Bildung
- ▶ Programme for International Student Assessment (PISA)
- ▶ Scientific Literacy: Its Relationship to "Literacy"

References

Abell S, Lederman N (eds) (2007) Handbook of research on science education. Lawrence Erlbaum Associates, Mahwah, New Jersey

Bybee RW (1997) Achieving scientific literacy: from purposes to practices. Heinemann, New Hampshire

DeBoer GE (2000) Scientific literacy: another look at its historical and contemporary meanings and its relationship to science education reform. J Res Sci Teach 37(6):582–601

Fensham PJ (2009) Real world contexts in PISA Science: implications for context-based science education. J Res Sci Teach 46(8):884–896
Hurd PD (1958) Science literacy: its meaning for American schools. Educ Leadersh 16(1):13–16
Organization for Economic Co-operation and Development (OECD) (2006) Assessing scientific, reading and mathematical literacy: a framework for PISA 2006. OECD, Paris
Organization for Economic Co-operation and Development (OECD) (2009) PISA 2009 Assessment framework-key competencies in reading, mathematics and science. OECD, Paris
Roberts D (2007) Scientific literacy/science literacy. In: Abell S, Lederman N (eds) Handbook of research on science education. Lawrence Erlbaum Associates, Mahwah, pp 729–780

Scientific Literacy: Its Relationship to “Literacy”

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Discussions of scientific literacy often propose answers to one or both of two distinct questions: (a) What is the meaning of scientific literacy? (b) What is the significance of scientific literacy? The first question tackles the semantic issue of how individuals in some specific group (say, a particular society) actually could, or should, use the expression. The second question deals with what is important about scientific literacy conceived in a particular way.

Meanings of “Literate” and “Literacy”

In modern English usage, the words “literate” and “literacy” have two distinct senses. “Literate” is the older of the two words, having been traced to the Latin “litteratus,” meaning “marked with letters,” and occurring first in late middle English in the fifteenth century. “Literacy” did not appear in usage until the late nineteenth century, which is when the meanings of the terms started to change. During most of the history of its usage, “literate” meant generally to be well educated and learned. Since the late nineteenth century, it has also come to refer to the abilities to read and write text. The transition in meaning that began slightly over 100 years ago has had such an effect that the Oxford Dictionary of English in 2012 reported “ability to read and write” as the primary meaning of literacy and “having education and knowledge typically in a specified area” as the secondary meaning.

Conceptions of Scientific Literacy in the 1950s and 1960s

In the field of science education, it is the second of the Oxford Dictionary of English usages that usually is found: that is, scientific literacy referring to being educated and possessing knowledge in science and about science. The term appeared in the science education literature during the middle of the twentieth century, being used by American-based scholars to express the need to increase attention to science education. Early uses of the term were by McCurdy (1958) and Hurd (1958). McCurdy’s desire was for an understanding of natural science to be part of a broad liberal education, in particular, to help allay confusions between science and technology that he saw as widespread in American society of the day. He sought a science course at the secondary school level that provided knowledge both of and about science through “familiarity with the history and accomplishments of science and its relation to the matters of everyday life . . . [and] emphasis upon the cultural roots and goals of science” (p. 369). Hurd saw the achievements of science as the defining characteristic of a modern society and took an “acquaintance with scientific forces and phenomena [as] essential for effective citizenship” (p. 13). He sought a science education both for continued scientific advancement and for enabling people to cope with change.

He recognized the enormous difficulty involved in selecting from the "tremendous volume of scientific knowledge and concepts" (p. 15) the small proportion that could be taught. His attention was more focused on learning experiences that foster "the development of an appreciation of science as an intellectual achievement, as a procedure for exploration and discovery, and which illustrate the spirit of the scientific endeavor" (pp. 15–16).

These early writers about scientific literacy all sought greater understanding both of and about science for members of society as a whole. This desire expressed their semantic notion of scientific literacy. Their reasons for seeking this goal expressed the values that they held for scientific literacy: the promotion of effective citizenship, the broadening of liberal education, the successful continuation of scientific achievements, the preparation to cope with a rapidly changing society, and the appreciation of and support for science.

By the mid-1960s, Pella et al. (1966) was able to define scientific literacy as "science for effective citizenship" (p. 199). This definition is skewed neither toward the sense of being knowledgeable in science nor toward the sense of being able to read science. Rather, the definition speaks more to the goals of pursuing scientific literacy than to what scientific literacy actually means. This coupling of goals to meaning became very common in discussions of scientific literacy over the past 50 or so years. Scientific literacy has become a programmatic concept, which is used not only to express meanings but also to urge particular educational objectives to reach favored moral and political ends. Pella traced the meanings of scientific literacy – science for the citizen and science for general education – through the two previous decades. He concluded that "The scientifically literate individual presently is characterized as one with an understanding of the (a) basic concepts in science, (b) nature of science, (c) ethics that control the scientist in his work, (d) interrelationships of science and society, (e) interrelationships of science and the humanities and (f) differences between science and technology" (p. 206).

Concern with Practical Problems

In the literature of the latter part of the twentieth century, most of the themes identified by Pella were maintained. However, many scholars began to think that scientific literacy conceived as such was disconnected or too far removed from the lives of nonscientific citizens. Thus, in addition to the focus on knowledge and understanding that was predominant in Pella's time, there emerged a growing concern with the possession of the kind of knowledge, understanding, and competence required to deal with practical problems that are science related, harking back to the early idea of science for effective citizenship. Discussions turned to such matters as the following: the ability to think scientifically about natural phenomena and to find answers to questions about them; the ability to use scientific knowledge and scientific ways of thinking in problem solving and in making informed decisions about one's well-being and that of others; the knowledge needed for intelligent participation by the nonscientific citizen in science-based social issues, including the knowledge needed to understand the issues and the communicative competence to reason about such issues with others and as they appear in various media; and the ability to think critically about science and to deal with scientific expertise, including the ability to make plausible assessments of risks, to formulate and evaluate positions on matters informed by science, and to offer and to assess arguments based upon scientific evidence to support those positions.

The Primary Sense of Scientific Literacy

Another line of thought, focusing scientific literacy on practical problems, that began to develop late in the twentieth century was that participation in public discourse about science-related issues requires an ability to interpret oral and written language and perhaps also to write on science-related issues. This recognition was the beginning of a turn in thinking about scientific literacy toward the primary sense of literacy, the ability to read and write. An early mention of scientific literacy in this primary sense was by Branscomb (1981), who in fact wanted scientific literacy to be understood broadly and was fearful that it might be defined "narrowly as the ability to read and write [science]" (p. 6), which in her view would exclude a large proportion of the population that relies on modes of communication other than text to gain information. In the science education field, early attention to the primary sense of scientific literacy was manifested in a special issue of the *Journal of Research in Science Teaching* (1994, Vol. 31, Issue 9) on the "reading – science learning – writing connection." In the ensuing nearly two decades, several variants have emerged of how the primary sense of literacy is related to scientific literacy.

Reading and Writing as a Central Scientific Practice

Scientists read a great deal. Evidence has shown that scientists derive most of their information through reading and read for nearly one-fourth of their total work time. Evidence also shows that scientists rate reading as essential. The award-winning and high-achieving scientists tend to read more than others. When writing time is factored in, scientists spend almost one-half of their working time involved in primary literacy activities. Science educators thus have begun to see reading (and writing) as core scientific practices. This change of perspective on the nature of science led educators to rethink the view that hands-on experience is *the* essential core of scientific practice and, as a result, the sine qua non of any respectable science curriculum. Once the view of scientific practice is altered to make room for literacy in its primary sense, failure to attend to reading and writing in science learning was interpreted as neglectful. Thus, by the turn of the millennium, several research programs were underway designed to develop an understanding of specific literacy practices that underlie science to incorporate those practices into science teaching and learning.

Reading and Writing as a Tool for Doing Science

Once the amount of time scientists spend reading and writing is recognized, the question naturally arises of the relationship between literacy and science. Observation, for example, has been seen as a defining feature of science, grounding its empirical character, and being used to distinguish science not only from creationism but also from philosophy and literature. In contrast, literacy practices often have been seen as tools scientists use to help them do science, as opposed to essential features of the nature of science. Thus, scientists might be described as readers and writers in order to accomplish their task of doing science, and students might be taught to read and write science as tools for learning science. The idea here is that the reading and the writing are not conceived as part of science itself, whereas, for instance, observation is.

Reading and Writing Science as Important for Effective Citizenship

Reading and writing science can be seen as important in science education because they afford citizens access to understanding articles about science in various media, including newspapers, magazines, television, and the Internet. The type of reading and writing seen as desirable is usually described as "critical," because the emphasis is on critically evaluating the conclusions contained in popular reports of science, communicating the substance of those conclusions to a third party, and engaging in social conversation about their validity. In contrast, the evidence overwhelmingly shows that students at all levels and the nonscientific public have difficulty interpreting such reports of science, even though they think the reading is easy. Their misjudgment has been traced to a method of literacy instruction in schools, colleges, and universities that emphasizes the recognition of words to the detriment of interpreting meaning.

Reading and Writing as Important to Learning the Nature of Science

The manner of language use helps define the nature of the practice. In school science textbooks and classroom instruction, language is used mostly to show, summarize, and define; to present facts and descriptions; and to develop vocabulary and descriptive accounts of natural phenomena. In science itself, language is used to demonstrate conclusions, to provide reasons for why things are as they are, and to argue for causal interpretations. During the first decade of the twenty-first century, science education scholars began to urge the point of view that science instruction can profitably capitalize upon the common epistemological footings of science and reading. Both science and reading involve inquiry, that is, analysis, interpretation, and critique. Thus, if science students are taught to interpret the meaning of science texts, to distinguish in those texts what is reported as observed from what is inferred, to identify the evidence offered for conclusions and the conclusions drawn on the basis of evidence, and to understand the descriptions of methodology, then through learning the nature of reading and writing science texts, the students will have learned something of the nature of science.

Reading, Writing, and Text as Constitutive of Science

A growing recognition in the first decade of the twenty-first century is that the two senses of scientific literacy cannot be understood independently. That is, there is no possibility of learning science without learning the literacy practices of science. The literacy practices are partly constitutive of science. Just as it is impossible to think of science absent its empirical character, the argument goes, it is impossible to think of science without its literacy character. That literacy character comprises all of the practices involved in producing and interpreting scientific texts, which are jointly and succinctly referred to as reading and writing in science. Therefore, it is impossible, according to this viewpoint, to be scientifically literate in the sense of having education and knowledge in science without being able to read and write science to a commensurate degree.

Cross-References

- ▶ Language and Learning Science
- ▶ Reading and Science Learning
- ▶ Scientific Literacy
- ▶ Writing and Science Learning

References

Branscomb AW (1981) Knowing how to know. Sci Technol Hum Values 6(36):5–9
Hurd PD (1958) Science literacy: its meaning for American schools. Educ Leadersh 16(1):13–16, 52
McCurdy RC (1958) Toward a population literate in science. Sci Teach 25:366–369, 408
Pella MO, O'Hearn GT, Gale CW (1966) Referents to scientific literacy. J Res Sci Teach 4:199–208

Scientific Values

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Science plays perhaps the most important role in the understanding of the universe. Science moreover contributes to the formation of values that effect social values. Therefore, there are many important characteristics and values that must be considered in scientific activities. Scientific outputs produced under the light of scientific values are important and scientists value these outputs. The fundamental value that must be obeyed by scientists in their research is honesty. The scientist has to report her/his experimental results without any falsificitation. The scientist must report the results with exact and understandable statements and must give detailed information about the materials and methods which are used in the research. The scientist before carrying out scientific research should not expect any commercial contribution from the research. The scientist must pay attention to the results of scientific research that contributes to humanity.

The scientist should also pay attention to the possible negative effects of research. In order to transform the research by scientists into real scientific values, there are many and extra important rules which must be followed by the scientists: reliability, testability, accuracy, precision, generalizability, and the appropriate statistical methods (Allchin 2012).

First of all, for turning scientific research into real scientific values, the research that is carried out has a novelty and it should not be a repetition of previous scientific research. In addition, the scientist should report all scientific results without fragmentation. When the scientists write their scientific research reports, they should write original statements and always properly cite the research of others. At the present time, the language of most of the platforms, the scientific journals, where the scientific researches are published, is generally English. This situation sometimes causes problems for scientists whose native tongue is not English. Even scientific research that is well designed and achieves important results can be rejected by the journal peer review process when the English is substandard. As a result, the language of the scientist can cause serious delays in the publication of valuable scientific research.

Another important parameter that the scientist should pay attention to is the use and evaluation of appropriate statistical tools and methods for the numerical values obtained from scientific researches. It is very well known that the different results can easily be obtained from different statistical methods. Therefore, the scientists should know detailed information on the statistics. When the scientist reports scientific research, there are general rules to be obeyed. For example, in the introduction part, the current literature should be summarized, and the gap within current literature should be defined very well. In the materials and methods part, the scientist should give details about materials and methods that they used. Sometimes, in scientific papers, researchers give appropriate citations to methodological papers instead of writing detail on the methods. As it is mentioned above, the results should be given exactly and without any falsification.

The scientist should pay attention to the effects of observer and also placebo effects. Therefore, especially in drug design researches, double-blind control groups should be used (Allchin 2012). Results should be compared with current literature knowledge and the reasons of parallel and nonparallel results should be explained. Novel findings must be emphasized and explained as a guide for other scientists interested in carrying out similar investigations. Research must be presented in peer-reviewed journals, but reviews must be based solely on scientific value, not influenced the personal characteristics of the researchers such as nationality, race, and religion. The evaluation should be objective. Therefore, to prevent any bias, the referees should be blind to authorship. Thanks to these values, science continues to improve our understanding of the universe and to the improvement of our lives.

Cross-References

- ▶ Cultural Values and Science Education
- ▶ Socioscientific Issues
- ▶ Values in Science

References

Allchin D (2012) Values in science: an introduction. http://www1.umn.edu/ships/ethics/values.htm. Retrieved 1 June 2012

Scientific Visualizations

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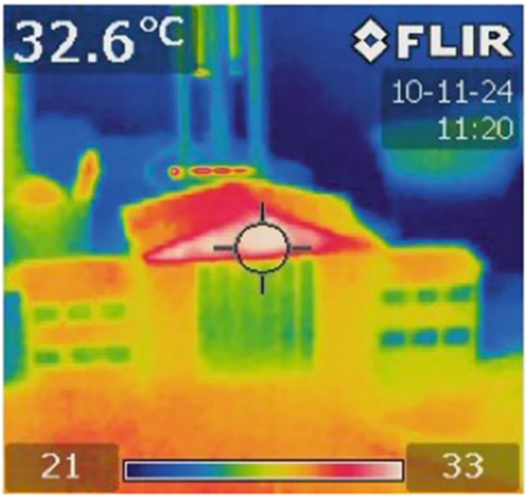
Keywords

Animation; Dynamic visualization; Simulation; Static picture

Scientific Visualizations

Visualization refers to either an internal or external representation of a concept, process, information, problem, or idea. Internal visualization encompasses a mental process whereby a person imagines some graphical or pictorial representation of information. An external visualization refers to an object or artifact that represents information graphically, pictorially, or sculpturally and may contain auditory or tactile elements. External visualizations can amplify the use or acquisition of knowledge by presenting large quantities of complex information visually. Both internal and external visualizations play important roles in science education in terms of representing science content, science processes, and the nature of science (Gilbert 2005). Indeed, researchers have argued that the mismatch between students' internal representations and the external ones presented in class or textbooks may account for some of the challenges in science instruction. Hence, much attention has been given to the careful design and application of external visualizations that are accessible to students and supportive of learning and instruction.

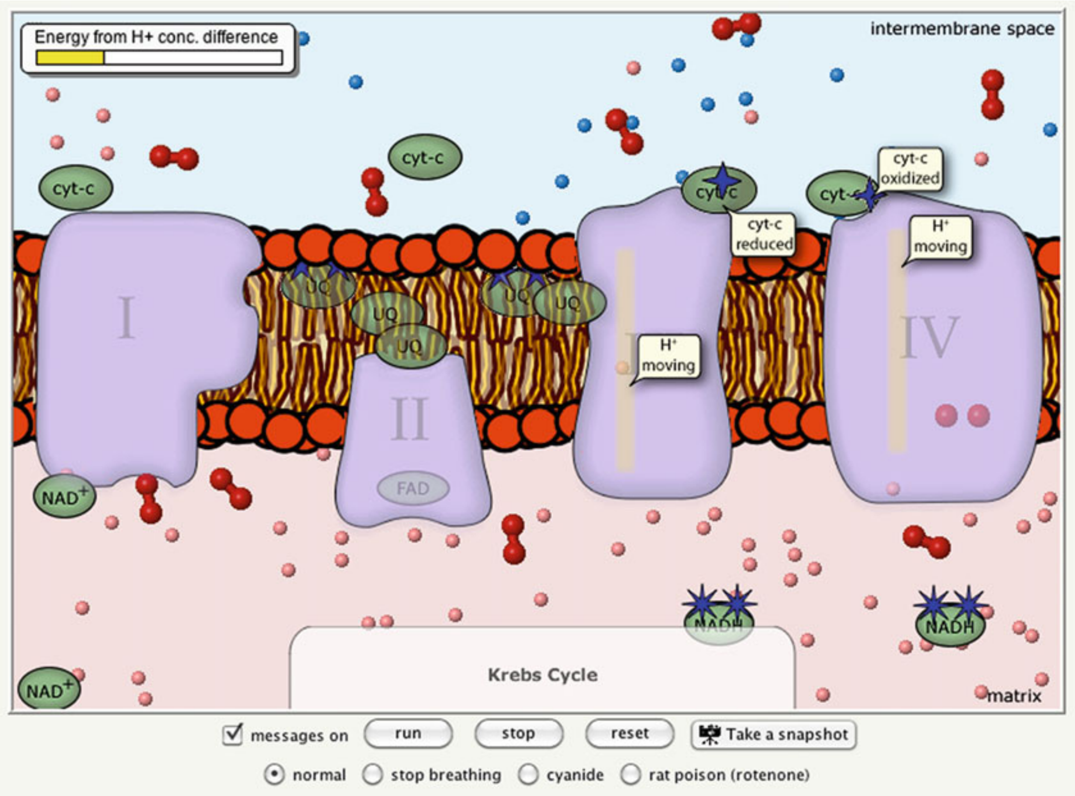
External scientific visualizations (henceforth scientific visualizations) can be used to communicate ideas and concepts and typically employ computer-based methods to represent theoretical concepts or physical data (e.g., from molecules, the human body, the Earth). Visualizations can serve to make abstract processes or concepts more explicit and concrete or to illustrate concepts that occur on very small (e.g., microscopic) or very large (e.g., astronomical or geological) scales. Instead of presenting complex data as sequences of numbers or text, scientific visualizations present data pictorially and graphically to take advantage of the human ability to process information and detect patterns through visual perception (Fig. 1).



Scientific Visualizations, Fig. 1 Infrared visualization of a model home (Image courtesy of Charles Xie)

Scientific visualizations can be grouped into three types: static, dynamic, and interactive visualizations. Static visualizations (i.e., images or graphs) do not change over time and do not allow any direct user manipulation. Typical static visualizations used in science include graphics, models, and diagrams found in research articles, journals, or presentations (for scientists) or in textbooks or lecture slides (for science students). Examples of static visualizations used in science education are models of atomic structure, pictures of organelles, or temperature isobars over a region of a country. Dynamic visualizations, or animations, do change over time or with user manipulation, resulting in the depiction of motion or progression. Examples of dynamic visualizations include animations of cellular processes, chemical reactions, or weather patterns.

Interactive visualizations differ from dynamic visualizations in that they are designed to be manipulated by the user, who thereby influences what the visualization presents. Simple interactive visualizations contain controls that enable the user to stop, start, replay, or step through an animation or sequence of static pictures. Complex interactive visualizations, like simulations or virtual experiments, are based on underlying computer models that enable users to change variables, parameters, or settings and explore resulting behaviors, dependencies, or outcomes (Fig. 2). For instance, a complex interactive simulation of electromagnetism might enable the user to change the "charge" settings and placement of objects, resulting in observable changes to the



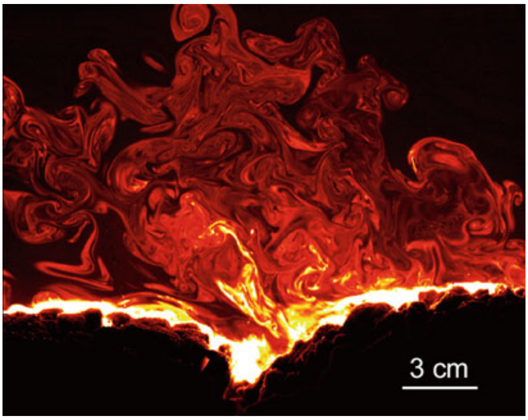
☑ messages on

● normal ○ stop breathing ○ cyanide ○ rat poison (rotenone)

Scientific Visualizations, Fig. 2 Molecular Workbench simulation of cellular respiration that enables students to experiment with different settings (normal breathing, no breathing, cyanide, and rat poison) (Image courtesy of Charles Xie)

electric field throughout the system. These visually rich, interactive visualizations enable students to construct their own understandings of complex phenomena by manipulating phenomena or processes that would otherwise be difficult or impossible to achieve in science classrooms.

Although scientific visualizations were first advanced as tools for practicing scientists, they have been adapted to help science students learn concepts and inquire about the world around them. For example, a scientist may use a dynamic visualization of fluid flow over coral reefs (Fig. 3) to communicate results about how corals exchange nutrients with the water; but students might use the same visualization (or a slightly simplified version) to learn basic concepts of fluid dynamics. Students can gain



Scientific Visualizations, Fig. 3 Scientific visualization of fluid flow used to investigate how corals exchange nutrients with the water (Photo courtesy of Matthew Reidenbach) practice in inquiry processes by making observations and inferences about visualizations and can learn to analyze data from the visualizations for purposes of addressing research questions. For example, learners might investigate infrared images of different conductors to explore questions about heat transfer. They might draw certain inferences or explanations from one set of images but could arrive at different conclusions when presented with a second set of images. Such investigations would support the development of inquiry skills as well as new understandings of the nature of science.

Different types of visualizations provide distinct affordances or opportunities for learning. Static visualizations provide students with concrete images of scientific concepts that might otherwise be too abstract, too large, or too small to be directly observed. For instance, static visualizations of electron orbitals can help students understand atoms, even though such orbitals are not actually perceivable, and only exist in a statistical sense. Importantly, such representations could also promote faulty interpretations, and developers of such materials must be sensitive to possible alternative interpretations that learners might derive. Students can refer to or engage with scientific visualizations at their own pace, returning multiple times, asking different questions, or debating their interpretation with peers or instructors.

Dynamic visualizations are often used for purposes of representing inherently dynamic processes such as rotations of molecules, DNA replication, or planetary motion. Dynamic visualizations can help students learn about complex scientific processes on very small or large scales that may not be easily communicated through sequences of static images. For instance, animations of cells dividing could help students understand the biological process of mitosis, or animations of electron movement in conductors could help students develop an understanding of electric current. As in the case of static visualizations, learners can make observations and inferences about dynamic visualizations and analyze that data to answer their questions and develop understandings about the nature of science. For example, two students looking at the same dynamic visualization might notice completely different events, which could lead to a discussion of how two scientists might differ in their interpretation of phenomena or experimental outcomes.

With simple interactive visualizations, such as visualizations with interactive controls, students can learn content at their own pace. For example, students using an interactive visualization of a cell can click on various organelles to obtain more information about the purpose of each organelle. This self-paced interaction allows learners to reach a better understanding as compared to just watching an animation passively. Complex interactive visualizations, such as simulations, provide a more extensive range of manipulations that can allow students to test their ideas, explore various conditions, and build a personal understanding of the relevant science concepts. Students can make predictions, test their ideas using the simulation, and receive feedback from the simulation itself that helps them consider revisions to their ideas or hypotheses. Simulations enhance inquiry-based approaches to science teaching, as students can engage in experimentation by manipulating variables and conducting virtual trials. For instance, in a simulation of natural selection, students could introduce mutations and explore their impact on population survival – something that is nearly impossible to do without interactive visualizations. Simulations can also contribute to an understanding that there is not “one” scientific method, as students may use multiple approaches to address the same research question.

Limitations of visualizations involve the inherent barriers of their particular representations. Static visualizations, for example, do not enable students to interact with the visualization and do not provide direct representation of dynamic processes. Simple dynamic visualizations that do not enable students to interact may result in students passively watching the animation without actively engaging with the information. Interactive visualizations enable learner control, but without adequate self-regulatory or self-monitoring strategies, learners may not take full advantage of the interactive affordances for learning. Visualizations are also limited to varying degree in the quality of their renderings, the complexity, or abstraction of information presented. Conceptual errors may have been introduced by attempts at simplifying scientific concepts.

Merely providing a learner with a visualization – whether static, dynamic, or interactive – does not guarantee that the targeted concepts will be communicated or learned. Research on learning with scientific visualizations highlights the importance of the design of the visualization, the design of supporting instruction, and the role of prior knowledge of the learner. Decreasing the unnecessary or distracting information while highlighting salient information will improve the accessibility and efficacy of any scientific visualizations (cf. Tufte 1990). Visualizations should be surrounded by supporting instruction that encourages students to make connections to existing ideas, reflect on their understanding, and revise their ideas. Instruction should also discuss limitations of any visualization employed, and what the visualization does and does not represent. For example, many images of atoms are presented in textbooks without explicit discussion regarding the limitations of the visualization. As a result, many students believe that we can actually see atoms directly, that atoms have color, that electron orbits have color and shape, and that chemical bonds are material objects – since they are often depicted as lines.

As with all instructional elements, students' prior knowledge will greatly influence what they learn from scientific visualization. For example, a visualization of cell processes may help a high school biology student to understand those processes more deeply, whereas a sixth grader might fail to understand the scientific content of the same visualization. Thus, design of both the visualization and the supporting instruction should pay careful attention to the expertise level of the intended audience. Pedagogical supports, such as lesson plans and assessments, and teaching notes, would also be important, to help teachers and learners derive the greatest advantage from visualizations.

Cross-References

- ▶ Digital Resources for Science Education
- ▶ E-Learning
- ▶ Models
- ▶ Multimedia Videos and Podcasting
- ▶ Multimodal Representations and Science Learning
- ▶ Online Media
- ▶ Representations and Learning in Science
- ▶ Science and Technology
- ▶ Simulation Environments
- ▶ Technology for Science Education: Research
- ▶ Visualization and the Learning of Science

References

Gilbert J (2005) Visualization in science education. Springer, New York

Tufte E (1990) The visual display of quantitative information. Graphics Press, Cheshire

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Scientists in Schools

▶ Scientist-School Interactions

Scientist-School Interactions

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Keywords

Informal science education; Partnerships; Science outreach; Scientists in Schools

Nature of Scientist-School Interactions

There are numerous ways in which scientists and other professionals working in science-related fields interact with schools to add value to formal science education programs. Some interactions are longer-term, ongoing relationships, while others are single occurrences. The nature of interaction varies widely and includes face-to-face visits as well as online interactions such as e-mail, Skype, blogs, discussion forums and chat rooms, or a combination of these. Some organizations and professional associations become involved so that their scientists can deliver specific outreach programs into schools. Universities may encourage their faculty to become involved in an attempt to attract more students to enroll in undergraduate studies at their institution. Particular industries may participate because they wish to encourage students to pursue science-related careers leading to employment in their field. The proportion of schools that have interactions with scientists is difficult to estimate but is almost certainly underrepresented in the literature because of the many interactions that are established through ad hoc, personal connections, such as a scientist being a parent at a particular school.

Scientist-school interactions may involve scientists working directly with students, teachers, or both. Types of interactions include a scientist presenting to a class or a number of classes; delivering a unit of work in conjunction with a teacher; mentoring students in open-ended science investigations; judging science fairs or other student work; participating in school science camps; supervising students or teachers undertaking research projects or work experience in the scientist's workplace; arranging student excursions to the scientist's workplace; assisting teachers, especially in primary or elementary schools, to identify and embed science in themed units of work; providing teacher professional development; and providing resources such as equipment or consumables.

Purpose

Regardless of the type or method of interaction, the broad purpose of involving a scientist with a school is to expose students to contemporary, real-world science and the work of science professionals. More specific aims are to stimulate and increase students' interest in studying science, increase students' awareness of careers in science, update teachers' knowledge of contemporary science, and increase awareness of the social and economic importance of science to the community. A secondary purpose, more commonly in primary or elementary schools, is to increase the profile of science in the school. Effective scientist-school interactions deliver successfully on these aims.

Contributions and Benefits

All scientist-school interactions share one distinguishing feature – the human element. For this reason they not only provide effective contributions to science content understanding but also demystify the image of scientists as being somehow different from ordinary people. Working directly with a scientist provides a unique, personal insight for students and teachers that is difficult to replicate with other curriculum experiences or programs.

The benefits of scientist-school interactions for the individuals directly involved have been well documented, and while the benefits for students and teachers may be obvious, the benefits for scientists are also significant. Benefits for students include increased engagement in science, the opportunity to see scientists as real people, having fun, increased awareness of careers in science, increased knowledge of contemporary science, and increased awareness of the nature of scientific investigation. Benefits for teachers include enjoyment from working with a scientist, updated knowledge of contemporary science, increased engagement by their students, increased confidence in teaching science, and increased profile of science in their school. Benefits for scientists include enjoyment from working with students and teachers, increased satisfaction with their own career, and increased confidence in communicating science. Scientists with school-aged children also report an increased knowledge and understanding of the school system as a benefit for themselves.

Characteristics of Effective Scientist-School Interactions

The success of scientist-school interactions depends on a variety of factors including thorough planning and preparation by the teacher so that the interaction, whether a single visit or ongoing relationship, forms part of a curriculum program; clear, mutually respectful communication between the scientist and teacher to clarify expectations of each other; the ability of the scientist to engage with students and teachers; and the flexibility of both parties to adapt as required. The question of whether longer-term, ongoing relationships are more effective than once-off, single interactions is worth considering. There is little on this topic in the literature, perhaps because longer-term interactions are not especially common due to the greater investment in time and effort that is required to sustain them. One of the documented characteristics of longer-term interactions is that the students and teachers develop a rich relationship with the scientist. This leads to additional benefits that range from simple efficiencies such as the scientist being able to find their way around the school through to the interaction adapting and becoming more refined as each party gains confidence and learns from previous experience.

Cross-References

- ▶ Citizen Science
- ▶ School-Community Projects/Programs
- ▶ Science Community Outreach

Search Engines

- ▶ Web 2.0 Resources for Science Education

Secondary Science Teacher Education

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Keywords

Knowledge; Learning; Science Teacher Education; Strategies; Teacher Education

Introduction

“We teach as we were taught.” These six words summarize the major challenge facing secondary science teacher education, both from the perspective of what science we teach and from the perspective of how we teach science at the secondary level. The tendency of new and experienced teachers to teach as they were taught has been recognized for decades. Less frequently discussed and explored is the tendency of science teacher educators to teach as they were taught. We now know from research a great deal more about so-called best practices and about how individuals learn. Unfortunately, it is simply not enough to present best practices and new insights into learning to new teachers as information. As they themselves struggle to find their pedagogical feet in practicum classrooms and early in their teaching careers, new teachers need to learn from experience as they also learn how to learn from experience. Secondary science teacher education requires carefully developed strategies for helping new and experienced teachers to change their teaching *habits* – acquired by watching their own teachers – as they change their teaching *frames*, the ways they typically think about how students learn science.

The Content of Science: What We Teach

Typically, the science content to be taught is set out for teachers in curriculum documents that differ from state to state and province to province. Each jurisdiction usually sets out additional requirements for attention to the processes of science as well as the content. In the context of secondary science teacher education, those learning to teach face the challenge of connecting science content to the everyday world of their students. Studying science in university courses in order to perform well on examinations is quite different from processing science content in ways that illuminate events in the world around us and help others to learn basic scientific concepts. Secondary science teachers also struggle with the tension between preparing a few students for further study of science and preparing all students for the understandings of science that help them see how biology, chemistry, physics, and earth and space science provide insights into everyday events from infections and reactions to collisions and earthquakes.

The Process of Science: How We Teach

Science teacher educators have focused for decades on issues associated with teaching science as inquiry and learning science for understanding of concepts rather than memorization of facts. Some universities have established groups that study how first-year university students learn a science subject; such research groups tend to focus on a single subject – biology, chemistry, or physics. These groups produce articles offering insights into the learning approaches and difficulties of first-year university students, and those insights can tell us a great deal about the learning achieved by senior secondary students who have gone on to university study. Knight (2004) has produced an outstanding analysis of the teaching of physics topics to first-year university students. His five recommendations (they are not easy to enact) should apply to all first-year university science teaching and certainly have implications for secondary science teaching:

1. Keep Students Actively Engaged and Provide Rapid Feedback.
2. Focus on Phenomena Rather than Abstractions.
3. Deal Explicitly with Students' Alternative Conceptions.
4. Teach and Use Explicit Problem-Solving Skills and Strategies.
5. Write Homework and Exam Problems that Go Beyond Symbol Manipulation to Engage Students in the Qualitative and Conceptual Analysis of Physical Phenomena (Knight 2004, pp. 42–45).

In this list we see clear and focused advice that reflects careful analysis of recent research on learning as well as Knight's study of his own teaching of physics students in their first year of university study. The advice is directly relevant to secondary science teaching. Each of his five lessons invites secondary science teachers to look carefully at their own teaching and at the learning of their students. This invitation is equally important for science teacher educators, who must consider whether or not this advice to science teachers can be applied to the work of preparing individuals to teach science at the secondary level. Knight's five lessons need to be modeled explicitly to beginning science teachers in order to provide them with personal experience of their impact on learning. The *phenomena of teaching and learning* tend to be more engaging than educational abstractions, and qualitative and conceptual analysis of *educational* phenomena certainly have an important place in secondary science teacher education. Teaching guided by Knight's advice is inherently complex and challenging. Modeling these principles and making it explicit that one is doing so is similarly complex and challenging; explicit analysis of one's own teaching as a science teacher educator may have more impact than any other strategy used with future teachers of secondary science.

Science Teachers' Knowledge of Practice

An important set of recommendations for secondary science teaching and teacher education appears in Loughran's (2010) consideration of the work of expert teachers. Drawing in part on his knowledge of the teaching insights developed within the Project for Enhancing Effective Learning (http://peelweb.org), Loughran presents six elements of expert teachers' knowledge of practice: prior knowledge, processing, linking, translation, synthesizing, and metacognition. Like so much recent research, Loughran highlights the importance of identifying and responding to students' prior knowledge; again, this is a significant consideration for science teacher educators. Processing, linking, translating (moving ideas from one context to another), and synthesizing are important elements of science teaching; the corresponding challenge for science teacher education is to incorporate these elements into the preservice teacher education experience in ways that provide those learning to teach with opportunities to practice and thereby develop appropriate skills for teaching. Finally, metacognition is a crucial element of secondary science teacher education. New teachers need to be able to regulate and monitor their own professional learning, and they need to develop skills for encouraging their students to become similarly attentive to their learning of science. To encourage these elements of expert teaching in our secondary science classrooms, they must be included within the learning experiences of teacher education for secondary science.

The Importance of Prior Knowledge in Learning to Teach Science

Much has been written about the importance of teachers' identifying and responding to views of scientific phenomena that students hold when they begin a course in science. Much less attention has been given to the views of educational phenomena that prospective teachers hold when they begin a course in learning to teach science. Insights into one classroom of secondary science teacher education are provided in Bullock's (2011) fine-grained analysis of the learning experiences of five individuals in a physics curriculum methods course in a 1-year initial teacher education program. The focus of the analysis is on how learning in the methods course related to and interacted with learning in practicum settings. The participants in the study were interviewed four times through their program, first in a focus group and then individually to explore more fully the views expressed in each focus group. This unique study of science teacher education illustrates clearly and powerfully that the prior knowledge (including teaching habits and frames of mind for thinking about teaching and learning) that a prospective teacher brings to a science teacher education program is a major influence on what that individual takes from the program. Gone are the days when science teacher educators might assume that all their students leave their classes with the same messages, including the ones that they were trying to develop and convey.

Learning to Identify the Effects of Teaching on Students

Education generally and teacher education in particular often appear to be short on knowledge of what works in practice. While there is much discussion of evidence-based best practices, that discussion is rarely accompanied by consideration of the complexity of changing personal teaching practices, which are typically habitual. Hattie's (2012, p. ix) central message is "Know thy impact," and this message is as important for science teacher educators as it is for science teachers. Hattie's own words speak clearly. "A major theme of this book... is that the quality of teaching makes all the difference." "The message in this book is that teachers, schools, and systems need to be consistently aware, and have dependable evidence of the effects that all are having on their students – and from this evidence make the decisions about how they teach and what they teach" (p. 149). "What is asked for here is a culture in which teachers spend more time *together* pre-planning and critiquing this pre-planning, and working in teacher groups to interpret the evidence about their effect on students" (p. 168).

These messages come from an individual who has studied research on teaching and learning for many years and who is urging us to place the emphasis on evidence of the effects of our teaching on our students' learning. These messages have more significance for science teacher educators than for science teachers in secondary schools; those whose work it is to prepare individuals to teach science at the secondary level need to gather continuously the evidence that they are encouraging, challenging, and enabling new science teachers to develop habits of practice and frames of mind that permit them to know their impact on the students they teach. Hattie's approach has several unique features. While it is important to work from the empirical evidence available about a range of teaching practices, Hattie stresses the importance of gathering evidence of the effects of one's teaching in one's own classroom and working with other teachers in one's school or college of education to interpret that evidence and collectively plan further development of teaching practices.

The Importance of Experience: Metacognition and Transformative Learning

Mezirow's (1997) theory of transformative learning has significant implications for secondary science teacher education. Just as secondary science teachers seek to transform students' common-sense views based on personal experience into richer and deeper understandings based on principled analysis of scientific phenomena, so secondary science teacher educators seek to transform prospective teachers' common-sense views of teaching and learning into richer and deeper understandings based on principled analysis of classroom events. Three common themes in the theory of transformative learning are the centrality of experience, critical reflection on that experience, and rational discourse as a means of learning. Experience is seen as socially constructed, so that it can be deconstructed and acted upon. It is experience that provides the grist for critical reflection. Major challenges for secondary science teacher education and teacher education generally continue to be the development of skills of critical reflection on practicum experiences and the linking of those experiences to what is presented in education courses.

Having experience and learning from experience are obviously related yet they are not the same. Without careful analysis and discourse with others, what we learn from experience is likely to be both incomplete and flawed. Just as everyday experience with natural phenomena often leads to incomplete and incorrect understandings, so everyday experience of students in classrooms leads to incomplete and incorrect understandings of why teachers display particular habits in their teaching. Identifying assumptions and developing links between theory and practice are some of the many activities that fall under the term *metacognition*. Those learning to teach have rarely been challenged to become metacognitive and thereby come to understand the nature of their own learning processes. The end goal of transformative learning is professional autonomy, and secondary science teacher education needs to promote this goal at every opportunity.

Overview

To summarize, secondary science teacher education shares many of the challenges and responsibilities associated with teacher education generally. Because science considers the phenomena of the natural world, science teachers can provide many firsthand experiences to their students to help them to refine and extend the views they have developed from prior experiences. Secondary science teacher education has the additional responsibility of providing experiences that will enable future science teachers to consider the phenomena of the educational world. Becoming metacognitive about one's own learning and the learning of others is central both to learning secondary science and to learning to teach it. We often teach as we were taught because the habits of teaching and learning and the frames of mind for education that we developed as students observing our own teachers tend to be stable and difficult to change. For science students, science teachers, and science teacher educators, reframing our perspectives and developing new habits go hand in hand. The parallels between learning science and learning to teach science are numerous and significant. The research on learning in general and learning science in particular offers challenging insights that can help shape new and transformative science teacher education practices that move beyond teaching as we were taught.

Cross-References

- ▶ Biology Teacher Education
- ▶ Chemistry Teacher Education
- ▶ Environmental Teacher Education
- ▶ General Science Teacher Education
- ▶ Inquiry, Learning Through
- ▶ In-Service Teacher Education

- ▶ Language in Teacher Education
- ▶ Metacognition and Science Learning
- ▶ Pedagogical Content Knowledge in Teacher Education
- ▶ Pedagogy of Teacher Education
- ▶ Physics Teacher Education
- ▶ Project for Enhancing Effective Learning (PEEL)
- ▶ Science and Mathematics Teacher Education
- ▶ Science and Society in Teacher Education
- ▶ Self-Study of Teacher Education Practices (S-STEP)
- ▶ Student Teacher as Researcher
- ▶ Student Teachers' Needs and Concerns
- ▶ Teacher Professional Development

References

Bullock SM (2011) Inside teacher education: challenging prior views of teaching and learning. Sense Publishers, Rotterdam

Hattie J (2012) Visible learning for teachers: maximizing impact on learning. Routledge, London

Knight RD (2004) Five easy lessons: strategies for successful physics teaching. Addison-Wesley, San Francisco

Loughran J (2010) What expert teachers do: enhancing professional knowledge for classroom practice. Routledge, London

Mezirow J (1997) Transformative learning: theory to practice. New Dir Adult Contin Educ 74:5–12

Self-Efficacy in Learning Science

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Keywords

Capacity beliefs

Self-Efficacy Beliefs for Science Teachers and Students

Teachers and students hold beliefs about their capabilities for teaching and learning science. These self-perceptions about personal abilities to manage engagement with science have been shown to causally influence success through motivation and the ability to do what is necessary in a given science learning environment. Such beliefs are known as self-efficacy beliefs and are different from more general beliefs of self-confidence and self-esteem in that they are targeted at specific future performance. Since all self-efficacy beliefs, including those for teaching and learning science, are malleable and have a causal relationship to success, it can be useful to include them in strategies to improve science education.

Self-efficacy study is rooted in Bandura's (1997) social cognitive theory and is composed of two dimensions: efficacy predictions and outcome expectations. These reflect the position that personal expectations of competence are tempered by the affordances of the context in which an individual will act. If a teacher or student expects that the environment in which they will teach or learn science will allow them success, then their chances of achievement are more likely (Dolin and Evans 2011). Conversely, when various factors exist which may inhibit successful science learning, then personal self-efficacies may be diminished. Studies show that while higher self-efficacies, motivation, and confidence to teach science often result from professional development, contextual outcome expectations may not be similarly elevated. For experienced teachers this may indicate a realistic assessment of the intractability of local teaching conditions including the perceived chances of actually making a difference with given students. Another explanation of increased self-efficacies and static outcome expectations after teacher development could be the inexperience teachers have at teaching with their newly increased capacity beliefs. Consequently, even though social cognitive theory includes both dimensions of self-efficacy (efficacy predictions and outcome expectations), studies also often look at the two constructs separately so that changes in efficacy predictions can be seen when different from outcome expectations.

High self-efficacies increase teacher and student motivation and success with teaching and learning science. Both are more likely to take risks, accept challenges, and try new ways of doing science when their self-efficacies are high. One of the most common uses of self-efficacy in science teaching over the past 20 years has been to gauge change in capacity beliefs during preservice methods courses and teacher professional development programs. A notable finding has been that an increased use of inquiry-based instruction of professional development is correlated with increases in self-efficacy (Dolin and Evans 2011).

Ameliorating Self-Efficacy

Given this potential, it is useful to know how personal self-efficacies are created and changed. Bandura (1997) describes four ways through which they naturally develop. Primary is the accumulation of **mastery experiences** relevant and specific to a future event through which we develop a sense of the likelihood of successful performance. When teachers have reasonable success with trying unfamiliar science teaching methods, they are more likely to predict that they will also experience some success at other methods they have not tried. Conversely, when students experience repeated failure when attempting to design an experiment with adequate controls, they will predict their continued failure and resist future attempts with such experimental design.

Another method by which self-efficacies are changed is through **vicarious experiences** where students may see peers similar to themselves competently conducting a science exploration and consequently feel that perhaps they too can do the same. This comparison with successful others raises their perceived self-efficacy at such tasks and means that they are more motivated to attempt explorations and more likely to do so competently. Conversely, a new teacher may hear from another science teacher that facilitating group work is not only difficult but likely to result in a loss of control over the classroom behavior. This message from someone the teacher compares themselves to may diminish their self-efficacy for using group work so that they may be more reluctant to attempt it.

The self-efficacies of both teachers and students are also affected by **social persuasion** from peers as well as from feedback to one another. When authentically encouraged or discouraged about their ability to facilitate or participate in a given science activity, teachers and students are more or less likely to be motivated to become engaged and their consequent success affected. The credible feedback which teachers can give to students about their ability to succeed at a specific science activity can significantly influence student self-efficacies and consequently their achievement. Likewise, genuine student feedback to teachers about their efforts can persuade teachers to attempt teaching strategies that may be new or uncomfortable to them.

Teachers and students partly use judgments of their own **physiological and emotional states** to decide how confident about a specific future task they feel. Teachers who are anxious about trying challenging teaching methods have reduced self-efficacies relevant to those methods and are less likely to take the necessary risks to attempt them. For students, anxiety about learning activities reduces their motivation to attempt them. As experienced teachers know, positive and negative moods for both students and teachers can contribute to self-efficacies and consequently the motivation to meet challenges.

Assessing Self-Efficacy

The quantitative instrument which has been most used for assessing self-efficacy among elementary teachers was developed by Larry Enochs and Iris Riggs' in 1990 and updated by Bleicher (2004). It consists of 23 five-choice questions with two integrated scales; one assesses self-efficacy beliefs for future science teaching activities and the other outcome expectations for those same actions. When used before, during, and after methods courses or professional workshops, relative changes in scores have provided teacher educators with information on change associated with professional development activities. Others have used qualitative assessments of efficacy based on interviews with teachers to judge changes. More recently, to narrowly focus on changes in efficacy beliefs, studies have looked at changes in beliefs associated with specific methods instruction, such as inquiry teaching (Dolin and Evans 2011).

Current Trends

Current work to improve science teaching and learning often focuses on purposefully using a combination of the four ways for developing capacity beliefs to raise teacher and student self-efficacies. Such methods assume that by intentionally focusing on raising these capacity beliefs, students and teachers will be more motivated and successful with science teaching and learning tasks. Most current efforts are aimed at both preservice teachers and experienced teachers participating in professional teacher development. Examples of such elements designed to increase self-efficacies in courses and workshops would include opportunities for teachers to try out new methods of teaching multiple times both with peers and then with groups of students and to get realistic yet supportive feedback each time. Such experiences in relatively controlled circumstances support increases in self-efficacy through **mastery**. Since each participant also gets a turn at teaching their peers, everyone gets to compare themselves with those they feel most alike and therefore through **vicarious** experience are able to raise their self-efficacies. At the same time, instructors as well as all of the teachers in the courses and workshops who witness the teaching episodes give critical yet supportive feedback to one another adding to capacity beliefs through **social persuasion**. Such microteaching experiences in thoughtfully structured circumstances have the potential to reduce **anxiety** and heighten moods as teachers gain specific confidence through incrementally successful experiences.

While this approach to increasing teacher capacity beliefs has shown positive results in motivation and success with science teaching methods, direct connections between the four ways for increasing self-efficacy and actual changes have not been made. Some current effort is aimed at discovering which ways are effective under which circumstances so that future intentional efforts to increase science teacher self-efficacy can be more effectively focused.

There has not been as much formal attention given to increasing student self-efficacy for doing science through conscious use of these four ways, although effective science teachers have long informally employed them for boosting pupil capacity beliefs. However, the implications of general self-efficacy studies are also applicable to managing science student self-efficacies (Pajares and Urdan 2006). Important for students is the expectation of desirable outcomes resulting from science activities. Perhaps more than for teachers, pupils' personal expectations of competence are diminished when they do not expect their efforts to be productive. Teachers can help students overcome this de-motivating effect of low expectations by authentically boosting student self-efficacies through well-structured mastery practice, opportunities for pupils to work with achieving peers, credible and supportive feedback, and attention to emotional barriers to good performance. The rewards are that students with higher self-efficacies are likely to put more effort into their academic work, stay with difficult problems longer, have more positive attitudes, and, in the end, achieve more.

Cross-References

- ▶ Affect in Learning Science
- ▶ Attitudes to Science and to Learning Science
- ▶ Cooperative Learning
- ▶ Emotion and the Teaching and Learning of Science
- ▶ Mindfulness and Science Education

References

Bandura A (1997) Self-efficacy: the exercise of control. Freeman, New York

Bleicher RE (2004) Revisiting the STEBI-B: measuring self-efficacy in preservice elementary teachers. Sch Sci Math 104:383–391

Dolin J, Evans RH (2011) Initial teacher education and continuing professional development for science teachers: a review of recent research results. In: Delhaxhe A (ed) Science education in Europe: national policies, practices and research. Education, Audiovisual and Culture Executive Agency P9 Eurydice, Brussels

Enochs LG, Riggs IM (1990) Further development of an elementary science teaching efficacy belief instrument: a pre-service elementary scale. Sch Sci Math 90:694–706

Pajares F, Urdan T (2006) Self-efficacy beliefs of adolescents. Information Age Publishing, Greenwich

Self-Evaluation

▶ Student Self-Assessment

Self-Study of Teacher Education Practices (S-STEP)

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Keywords

Practitioner research; Reflective practice; Self-study

Background

Self-study of teaching and teacher education practices, abbreviated as S-STEP, or self-study, is a genre of educational research concerned with examining and improving the relationship between teaching and learning in teacher education contexts. In self-study, the teacher educator him/herself is both the researcher and the main focus of the study. Self-study is concerned with the acquisition and development of teacher educators' knowledge of practice and how such knowledge can inform and enhance learning and teaching about teaching. The process of knowledge development in self-study is initiated through the teacher educator's capacity and willingness to publicly problematize his/her taken for granted beliefs and practices about teaching and learning; to be open to, and act upon, the curiosities, surprises, and challenges of everyday teaching practice; and to actively seek out alternative perspectives on practice.

The knowledge produced through self-study is intended both as a means of reframing the teacher educator's personal understandings of practice and stimulating the development of knowledge of practice among the community of teacher educators more broadly. An important function of self-study has been to promote the idea of teaching as a discipline and teacher educators' professional knowledge as specialized and unique.

Historical Roots

Self-study emerged as an organized field of research in the 1990s and was formalized with the founding of the Self-Study of Teaching and Teacher Education Practices (S-STEP) Special Interest Group (SIG) of the American Educational Research Association (AERA) in 1993. Since that time, self-study has acquired a scholarly and organizational presence in the international teacher education community and is recognized as a bona fide genre of research and topic of interest in teacher education practice and research. Consolidation of the field is evident through the production of an International Handbook (Loughran et al. 2004); a peer-reviewed, international journal, *Studying Teacher Education*; and a biennial conference, *The International Conference on Self-Study of Teacher Education Practices*.

Self-study is a qualitative research methodology that shares similarities with practitioner research, action research, and reflective practice. While the distinctions among these forms of research may be blurred, its explicit inclusion of "self" as the focus of study distinguishes self-study from other forms of qualitative research. Self-study researchers draw on a range of strategies in developing, conducting, analyzing, and representing their work. Mostly, these are typical of data-gathering approaches used in qualitative research. Important to self-study is that the researcher carefully selects a range of approaches to data gathering that offer multiple and alternative perspectives on practice. LaBoskey (2004) identified five key elements of self-study: it is self-initiated and focused, is improvement-aimed, is interactive, uses many strategies, and defines validity as a process based on trustworthiness.

Self-Study and Subject Matter

Self-studies are conducted by teacher educators in a broad range of topic areas, contexts, and locations, with many examples readily available in the literature. Typical themes of self-study research by teacher educators include the transition experiences of newly appointed, university-based teacher educators; studies of the implementation of particular philosophies in teacher education programs and courses; the development of subject-specific knowledge for teaching teachers; teacher educators articulating their pedagogy of teacher education; and teacher educators' efforts to address social issues of race, class, and gender.

Self-study has not typically tended to be based around any particular subject/content field. Rather, it has been the teacher education context that has been important. However, in recent times researchers in some areas have published their studies (see, e.g., social sciences (Crowe 2010) and mathematics (Schuck and Pereira 2011) with science education encapsulated in the work of Bullock and Russell (2012)).

Bullock and Russell's *Self-studies of Science Teacher Education Practices* (2012) illustrates how the interaction of science and self-study leads to new understandings of practice similar to those recognized in the science teacher research literature, including recognizing alternative conceptions and learners' prior views, facilitating a constructivist perspective, and confronting technical-rational views of teaching and learning.

Bullock and Russell's edited collection offers insights into teaching and learning about teaching through self-study across the fields of early career teacher educator practices, elementary/primary science teacher education, secondary science teacher education, and, preservice students' learning about science teaching and learning. Their text illustrates well how "self-study methodology offers one way to move beyond technical rationality toward a more productive understanding of professional knowledge" (p. 1).

Cross-References

- ▶ Pedagogy of Teacher Education
- ▶ Teacher Research

References

Bullock SM, Russell T (eds) (2012) Self-studies of science teacher education practices. Springer, Dordrecht

Crowe A (ed) (2010) Advancing social studies education through self-study methodology: the power, promise, and use of self-study in social studies education. Springer, Dordrecht

LaBoskey V (2004) The methodology of self-study and its theoretical underpinnings. In: Loughran J, Hamilton ML, LaBoskey V, Russell T (eds) International handbook of self-study of teaching and teacher education practices. Kluwer, Dordrecht, pp 817–870

Loughran J, Hamilton ML, LaBoskey V, Russell T (eds) (2004) International handbook of self-study of teaching and teacher education practices. Kluwer, Dordrecht

Schuck S, Pereira P (eds) (2011) What counts in teaching mathematics: adding value to self and content. Springer, Dordrecht

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Semiotic Modes and Science Learning

▶ Multimodal Representations and Science Learning

Sex Education and Science Education

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The Lens of Human Reproduction

School and college science typically examines issues of sexuality through the lens of human reproduction. This immediately tends to assume heterosexuality. Biology is all too often presumed to be a neutral subject so that many biology teachers and lecturers continue to teach it as an unquestioned fact. In particular, differences between females and males are often presented as clear-cut and inevitable, and the study of school biology textbooks shows that they are often sexist and typically ignore lesbian and gay issues (Reiss 1998). For example, they often omit all mention of the clitoris and, when they do refer to it, frequently talk of it in a belittling way as the female's equivalent of a penis. Males are rendered visible, females less so; the female exists by virtue of comparison with the male. When homosexuality is addressed, it is generally portrayed as a sort of second-best option, which the reader may well grow out of. However, closer examination of sex in human biology provides plenty of space for critical reflection and allows for a richer understanding of what it is to be a sexual person.

Emily Martin (1991) has shown that while menstruation is viewed in scientific textbooks as a failure (a successful woman would have got pregnant), sperm maturation is viewed as a wonderful achievement in which countless millions of sperm are manufactured each day. Furthermore, sperm are pictured as active and streamlined, whereas the egg is large and passive, drifting along or waiting. The way the egg is portrayed in science textbooks has been likened to that of the fairy tale *Sleeping Beauty*, in which a dormant, virginal bride awaits a male's magic kiss. However, for well over a decade, biologists have considered the egg and sperm as *active* partners. Just as sperm seek out the egg, so the vagina discriminates between sperm and the egg, seeking out sperm to catch.

Social historical research on sex hormones documents that textbooks and scientific papers give messages that go well beyond what the data indicate. For example, since the 1920s it has been known that each sex contains the "other's" hormone (i.e., males contain estrogen and females testosterone). Nevertheless, school science textbooks often ignore both this fact and the close chemical similarity between estrogen and testosterone. Indeed, school textbooks more in line with the scientific evidence about the working of sex hormones would present femaleness and maleness on a continuum (a model common among academic endocrinologists since the 1940s).

The Impact of Faith Groups

School sex education is frequently a contested area for members of faith groups (Halstead and Reiss 2003). Generalizations are difficult because of the variations that occur both within and between religions. Consider, for example, Islam. A core belief of this religion is that God created sexual duality – i.e., male and female – in creation. In both men and women, there is therefore a natural desire for companionship with the other sex. Accordingly, celibacy is not praised. Rather, sexual union gives a foretaste of the joys of paradise, and sexual relations are recognized as one of the great signs of the blessings Allah has bestowed on humankind. While there is a gay and lesbian Muslim movement, there is overwhelming support in Islam for the teaching that homosexuality is unnatural and abhorrent. Muslims feel uncomfortable about sex education conducted within a secular framework, and there are three main aspects of much contemporary practice in Western school sex education that give rise to Muslim opposition:

- Some sex education materials offend against the Islamic principle of decency and modesty.

- Sex education tends to present certain behaviors as acceptable which Muslims consider sinful.
- Sex education is often perceived as undermining the Islamic concept of family life.

Christian views about sex, as about virtually everything, derive from five main sources: the writings of the Bible; the teachings of the Church down the ages; the conscience of individuals informed, they believe, by the Holy Spirit; their God-given, though imperfect, powers of reason; and the particular cultural milieu they inhabit. Marriage has a mystical element to it, the relationship between a married couple reflecting the relationship Christ has with his Church. Indeed, in the Roman Catholic tradition, marriage is one of the sacraments. Christian attitudes to sex before marriage have softened in recent decades. However, homosexuality remains contentious. Some argue that it is clearly prohibited by scripture. Others maintain that both the Old and New Testaments knew little or nothing about mutually faithful adult-to-adult expressions of homosexuality, instead prohibiting cult prostitution and pederasty.

Cross-References

▶ Biology, Philosophy of
▶ Social Studies Education and Science Education

References

Halstead JM, Reiss MJ (2003) Values in sex education: from principles to practice. Routledge Falmer, London

Martin E (1991) The egg and the sperm: how science has constructed a romance based on stereotypical male-female roles. Signs J Women Cult Soc 16:485–501

Reiss MJ (1998) The representation of human sexuality in some science textbooks for 14–16 year-olds. Res Sci Technol Educ 16:137–149

Simulation

▶ Microworlds
▶ Scientific Visualizations

Simulation Environments

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Description

Simulations are a representation of real or hypothesized phenomena used to support learning through illustration of and experimentation with the system. Simulations enact the dynamic processes of a system and often allow the user to manipulate key factors affecting the dynamics in order to explore possibilities, generate hypotheses, or test predictions. Learning with a simulation may be centered around understanding the rules and assumptions that guide the simulation's dynamics or manipulating variables that normally may not be accessible (National Research Council 2011). For example, an interactive simulation of Newtonian physics may allow users to explore and develop theories about mechanics by applying impulse forces to objects and observing the results (diSessa 1982; Clark et al. 2011).

Simulations are typically open-ended with no set directives or roles other than those generated by the user or context of use. In contrast, games and other pedagogies may incorporate a simulation as a part of the learning experience but add an explicit roles or goals that shape interaction. Learning experiences with simulations include (a) using simulations by testing out a variety of scenarios to discover the rules that drive an extant simulation and (b) constructing simulations by studying already occurring phenomena and abstracting/reproducing key concepts in order to virtually reproduce them. The process of simulation construction is often iterative, with learners generating and testing different theories in order to reproduce observed behaviors.

Cross-References

- ▶ Games for Learning
- ▶ Microworlds

References

Clark DB, Nelson BC, Chang HY, Martinez-Garza M, Slack K, D'Angelo CM (2011) Exploring Newtonian mechanics in a conceptually-integrated digital game: comparison of learning and affective outcomes for students in Taiwan and the United States. Comput Educ 57(3):2178–2195. ISSN:0360-1315, 10.1016/j.compedu.2011.05.007

Colella V (2000) Participatory simulations: building collaborative understanding through immersive dynamic modeling. The Journal of the Learning Sciences 9(4):471–500

diSessa AA (1982) Unlearning aristotelian physics: a study of knowledge-based learning. Cogn Sci 6:37–75

Metz KE, Hammer DM (1993) Learning physics in a computer microworld: In what sense a world? Interactive Learning Environments 3(1):55–76

National Research Council (2011) Learning science through computer games and simulations. The National Academies Press, Washington, DC

Resnick M (1994) Turtles, termites, and traffic jams: explorations in massively parallel microworlds. Mit Press

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Single-Sex Classes in Science

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Keywords

Science

Single-sex classes have been introduced into coeducational schools – and in some cases universities – in numerous countries, including Australia, England, New Zealand, Sweden, and the USA. Although a few coeducational schools have implemented single-sex classes throughout the whole school and across all curriculum areas, in most cases they are introduced in specific subject areas and/or for particular age groups. Often, they are introduced with an aim of fostering engagement of girls in "masculine" curriculum areas (e.g., math) or boys in "feminine" curriculum areas (e.g., languages).

Concerns about the underrepresentation of women, compared to men, in science, technology, engineering, and math (STEM) frequently underpin initiatives to teach these subjects in single-sex classes. Arguments for single-sex classes vary. Some argue that there are innate differences between boys and girls that means they learn differently and, therefore, need to be taught differently. However, there is very little evidence to support this argument. Furthermore, such views ignore evidence which suggests that variations within groups of girls and boys are as significant as those between them. On the basis of the available evidence, many scholars reject the notion that there are innate sex differences in learning styles. However, some of these scholars still see benefits in single-sex classes, but for reasons based on social, rather than biological, factors. In relation to STEM subjects, such social arguments tend to acknowledge the effects of long-standing associations between STEM subjects and masculinity, which can have implications for how girls identify, or not, with STEM subjects and also how girls are treated in classrooms. For example, research has suggested that in mixed-sex science classrooms, girls are often marginalized and sometimes sexually harassed; boys dominate the space and equipment; and girls' confidence is frequently undermined. By contrast, single-sex science classes tend to provide more supportive climates for girls in which they build confidence and realize that girls can do science.

Are Single-Sex Science Classes Beneficial?

Researchers have attempted to measure the effectiveness of single-sex science classes in relation to various criteria, including academic attainment; pupil self-concept levels; continuation of the subject beyond compulsory level; confidence; and attitudes toward, and enjoyment of, the subject. Taken as a whole, the findings are mixed, although the weight of evidence suggests that single-sex classes may be beneficial for girls in some ways, for example, in increasing confidence. Reasons for generally inconclusive findings include that many single-sex initiatives are short-lived and often the schools are not clear about the precise purpose of them. Also, schools often implement single-sex classes alongside other schemes or changes, so it is difficult or impossible to disentangle the effects of these. In general, the ways in which single-sex classes are introduced and executed are important determinants of their success; the commitment and support of staff, students, and parents to such initiatives are particularly important.

Criticisms of single-sex science classes frequently relate to how they are taught. For example, there has been important and sustained criticism of programs that treat girls and boys as homogeneous groups and that reinforce pernicious gender stereotypes by tailoring the curriculum in gender-specific ways. Similarly, male classroom teachers who encourage male bonding in all-boys' groups by fostering sexist, macho, or "laddish" attitudes and behaviors have been criticized strongly by pro-feminist and feminist researchers.

Overall, evidence about the benefits of single-sex science classes is mixed. To maximize the potential benefits of such schemes, it is important to be clear about the precise purposes; to ensure staff, students, and parents are well informed and committed; and to implement them in ways that challenge, rather than reinforce, gender stereotypes.

Cross-References

- ► Gender
- ► Gender-Inclusive Practices

References

Jackson C (2002) Can single-sex classes in co-educational schools enhance the learning experiences of girls and/or boys? An exploration of pupils' perceptions. Br Educ Res J 28(1):37–48

Martino W, Mills M, Lingard B (2005) Interrogating single-sex classes as a strategy for addressing boys' educational and social needs. Oxf Rev Educ 31(2):237–254

Parker LH, Rennie LJ (2002) Teachers' implementation of gender-inclusive instructional strategies in single-sex and mixed-sex science classrooms. Int J Sci Educ 24(9):881–897

Younger M, Warrington M (2006) Would Harry and Hermione have done better in single-sex classes? A review of single-sex teaching in coeducational secondary schools in the United Kingdom. Am Educ Res J 43(4):579–620

Situated Cognition

► Situated Learning

Situated Learning

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Keywords

Cognitive apprenticeship; Situated cognition; Situated learning; Transfer of learning

A Situated View on Learning and Cognition

The traditional view of schooling treats knowledge as an independent entity, consisting of abstract, decontextualized formal concepts, which should be transferred from an external source to the learner. A problem with teaching practices based on this view is that they often lead to isolated and inert knowledge. Knowledge domains acquired through traditional schooling are often learned and stored in memory isolated from each other and therefore difficult to access. Inertness of knowledge refers to the problem that students are not well capable of using the knowledge they have acquired to solve problems in practice.

The key idea of situated learning is that knowledge and cognition cannot be separated from the situations in which they are learned and used. The notion of authentic activity plays a key role in this view of learning and cognition. The activities through which people develop knowledge are an integral part of the knowledge itself. Understanding is developed through continued use of concepts in authentic situations. The meaning of concepts evolves through this repeated use and is dependent on the way the concepts are used in a particular culture. Concepts are like tools: the use of them is not self-evident but defined by the way the tools are used in a particular community of practice. In this situated view, learning must involve activities, concepts, and culture, as these three are interdependent. Learning is seen as a process of enculturation in socially organized practices, through which knowledge, understanding, and practices are developed. A student must enter a community of practice and its culture to be able to learn to use the (conceptual) tools in the same manner as the members of that community use them. To learn to think like a practitioner (e.g., a mathematician, chemist, biologist), a student must learn to use the conceptual tools in authentic practice. Students need to be able to use a domain's conceptual tools in authentic activity and to be able to observe teachers who, as experts in the domain, are using those conceptual tools in trying to solve authentic problems in the domain.

Situated Learning and Transfer of Learning

In the situated view of learning, students should learn cognitive tools embedded in the situations in which they are acquired and used. Consequently, the knowledge is bound to those situations. However, in education we often want students to learn to also use their knowledge in situations beyond those in which the knowledge was acquired. Therefore, a tension may exist between the desirability of situated learning and the transfer value of the cognitive tools that students learn. Transfer value presumes that thinking strategies are not exclusively bound to those situations in which they were learned, but that they can also be applied in novel situations and on novel problems. Two types of transfer are low-road and high-road transfer. Low-road transfer is achieved through continuous practicing of strategies, in a variety of situations, until they are automatized. High-road transfer is achieved through deliberate abstraction and decontextualization of strategies. These two forms of transfer have strong similarities with the ideas of "near" and "far" transfer that were used in many science learning studies in the 1970s.

Transfer rarely occurs spontaneously. Learners should explicitly be pointed to similarities between the situations in which knowledge was acquired and other novel situations or domains. The best way to achieve both situated learning and transfer does not seem to be to create a kind of compromise between the two, but to emphasize both actively and alternately.

A Cognitive Apprenticeship View of Teaching

The view that all learning is situated in nature leads to a view of teaching as enabling cognitive apprenticeship. A famous ethnographic study by Jane Lave among African tailors showed very vividly how new apprentices started to learn becoming tailors by participating in the periphery of a community of practitioners. Gradually, as they gained experience with the craft of tailoring, they moved from the periphery to the center of the community. In a similar way, in cognitive apprenticeship students are enculturated into cognitive authentic practices.

Learning is viewed as developing a way of thinking and acting that characterizes the culture of a community of practice. In this type of learning, knowledge is continuously connected to the thinking activities which construct, modify, and use this knowledge to interpret situations in that domain and to act in those situations. In this way teaching and learning of conceptual tools (knowledge, cognitive skills) is integrated with the learning and teaching of the subject domain. Domain knowledge ("knowing what") and strategic knowledge ("knowing how") are taught in continuous coherence. The role of the teacher is one of model, activator, monitor, and evaluator of students' thinking, learning, and problem-solving strategies. Teachers may model these strategies by making overt and explicit knowledge construction and utilization activities that usually stay covert and implicit. Teachers may activate students to use learning and thinking activities that they do not use on their own initiative by means of questions, assignments, etc. When students get more skilled in the use of certain learning and thinking activities (cognitive tools), the role of the teacher may change towards monitoring the use of these strategies in students' self-regulated learning and provide students with feedback on their strategy use. Finally, teachers may want to evaluate the quality of students' strategy use. This paradigm is known as situated modeling, coaching, and fading, an essential element of any apprenticeship model ("scaffolding").

Regarding the regulation of learning, cognitive apprenticeship is characterized by a gradual shift in the task division in the teaching – learning process from the teacher to the learner. First, an explicit control structure is offered to the students, and subsequently this help and support is gradually withdrawn. Simultaneously, students are stimulated to internalize this external regulation of their learning processes, and they are taught the skills needed to do so. Learning to think like a practitioner then means a gradual transfer of control over learning and thinking processes from the teacher to the learners, a gradual shift from external to internal (self) regulation of learning and thinking.

Implications for Science Education

Examples of situated learning and cognitive apprenticeship models in science education are Schoenfeld's teaching of problem solving in mathematics; Freudenthal's realistic mathematics education; context-based approaches in chemistry, physics, and biology education; and problem-based approaches in health and medical science education. In Schoenfeld's approach, students may bring problems to the classroom that teacher and students investigate together in a mathematical way. The teacher and students think aloud and make their mathematical thinking as overt and explicit as possible. In this way, students can witness their teacher's and fellow students' mathematical thinking in authentic practice ("modeling"). In realistic mathematics education, students work on problems that are derived from realistic situations connected to their concrete life experiences. The idea is that students learn mathematics by doing mathematics. The teacher guides the students in "mathematizing" the concrete, realistic problems and going through a process of "guided reinvention" to discover mathematical principles in the problems.

In context-based approaches to chemistry, physics, and biology education, students study authentic situations in society in which science knowledge plays a natural role. They work together on solving a certain problem in a meaningful context, guided by the teacher. Learning is aimed at the continuous connection of important (chemical, physical, biological) concepts to meaningful contexts that students are familiar with from their own experience. In problem-based health and medical science education, for example, the start of the learning process is a problem: a short description of a phenomenon about which students should acquire knowledge. These problems are mostly derived from authentic professional practices. Under the guidance of a tutor, students work together in small groups trying to understand, explain, and solve the problem, during which they develop learning goals for independent study. The knowledge gained from independent study is exchanged between members of the group and used to understand and explain the problem.

Cross-References

- ▶ Communities of Practice
- ▶ Metacognition and Science Learning
- ▶ Problem-Based Learning (PBL)
- ▶ Scaffolding Learning

References

Brown JS, Collins A, Duguid P (1989) Situated cognition and the culture of learning. Educ Res 18(1):32–42
Clancey WJ (1997) Situated cognition: on human knowledge and computer representations. Cambridge University Press, Cambridge
Collins A, Brown JS, Newman SE (1989) Cognitive apprenticeship: teaching the crafts of reading, writing, and mathematics. In: Resnick LB (ed) Knowing, learning, and instruction: essays in honor of Robert Glaser. Erlbaum, Hillsdale, pp 453–494
Hennessy S (1993) Situated cognition and cognitive apprenticeship: implications for classroom learning. Stud Sci Educ 22:1–41
Sawyer RK, Greeno JG (2009) Situativity and learning. In: Robbins P, Aydede M (eds) The Cambridge handbook of situated cognition. Cambridge University Press, Cambridge, pp 347–367

Slow Animation

▶ Slowmation

Slowmation

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Keywords

Animation; Multimodal; Representation; Slow animation; Stop-motion animation

A “slowmation” (abbreviated from “slow animation”) is a simplified way for university or school students to design and make a stop-motion animation that is played at 2 frames/s providing a slow-moving image that is narrated to explain a science concept (Hoban 2005). It is an innovative way for students to learn science because they engage with a concept in many different ways when creating a slowmation by (i) reading text/images and making summary notes, (ii) creating a storyboard to plan the explanation, (iii) making or using existing models, (iv) taking digital still photos of models as they are manually moved, and (iv) using technology to integrate different modes that make up the final animation.

The explanation can be enhanced with narration, text, or music and is an engaging way to learn because students conduct research and use their own technology to design a sequence of representations culminating in the slowmation, which is a multimodal digital representation (Hoban et al. 2011). The process is very accessible because students use widely available technology such as a digital still camera, a tripod, and any free movie-making computer software.

Through creating a slowmation, students make a sequence of representations as a *cumulative semiotic progression* and their learning is influenced by their prior knowledge, the affordances of the representations created, and the social interactions involved (Hoban and Nielsen 2013). Free examples, instructions, and resources can be found at www.slowmation.com.

Cross-References

- ▶ Explaining as a Teaching Strategy
- ▶ Model of Educational Reconstruction
- ▶ Models
- ▶ Multimodal Representations and Science Learning
- ▶ Representations in Science
- ▶ Visualization and the Learning of Science

References

Hoban G (2005) From claymation to slowmation: a teaching procedure to develop students’ science understandings. Teach Sci 51(2):26–30
Hoban G, Nielsen W (2013) Learning science through creating a “Slowmation”: a case study of preservice primary teachers. Int J Sci Educ 35(1):119–146
Hoban G, Loughran J, Nielsen W (2011) Slowmation: preservice primary teachers representing science knowledge through creating multimodal digital animations. J Res Sci Teach 48(9):985–1009

Smartphones

► Handheld Devices

Social Epistemology of Science

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Keywords

Context of discovery/justification; Critical thinking; Philosophy of science; Scientism; Sociology of science; Veritism

Broadly speaking, social epistemology is concerned with normative questions surrounding the organization of knowledge, which is presumed to have an inherently social character (Fuller 1988). A natural way to interpret education in this context is as a promoter of democracy in the knowledge system, specifically by divesting innovative research of its originally elite character by including it in a curriculum available to many (Fuller 2009, Chap. 1). Thus, what first surfaced in specialist journals and monographs later appears in a more digestible form in widely used textbooks. Of course, if by "science" we mean the natural sciences, the relevant translations may require considerable effort. In any case, pedagogy is more than a simplified version of the research process. Rather, its challenge is to demonstrate an easier way to understand an important scientific finding than simply retracing the steps by which it was originally made. Thus, William Whewell (discussed below) distinguished what we now call the "context of discovery" and the "context of justification," the latter understood as the more efficient ex post facto way of reproducing the former. However, the relevant sense of "efficiency" is not merely a reduction in the number of steps needed to grasp the discovery but also an extension of the discovery's significance beyond the intellectual horizons of the original discoverer.

Positions in the social epistemology of science education may be understood in terms of the prospects of realizing this sense of efficiency. Pessimists generally believe that the most we can achieve is the reproduction of elite knowledge in relatively small groups through specialist science education, to which the rest of the population then learns to defer. This has been the path increasingly pursued by "analytic social epistemology," as discussed in the second part of this entry. However, the first part deals with the more generally – though not completely – optimistic approach to the task that has been undertaken in the history of the philosophy of science.

Philosophies of Science as Social Epistemologies of Education

Much of the philosophy of science has been informed, if not outright motivated, by science education concerns, ranging from the university to the school. The eminent natural theologian William Whewell, who coined "scientist" in the 1830s to describe a specialized profession, lobbied to include natural science instruction in Cambridge to enable students to understand the epistemic bases for the ongoing Industrial Revolution (Fuller 2000, Chap. 1). In practice this meant an appreciation of the method of hypothesis and the explanatory power of general theories. In a rather more democratic spirit, Ernst Mach campaigned at the end of the nineteenth century for using the applied arts and other forms of folk knowledge as platforms for formal scientific training in the secondary school curriculum (Chap. 2). He located the value of science more in its contributions to an individual's cognitive economy than in any high-order form of knowledge it might produce. This put Mach at odds with the professional physics community of his day, which stressed the worldview-building (*Weltbild*) character of the discipline. Nevertheless, his perspective proved influential on the logical positivist movement, several of whose members had come to be exiled from physics to philosophy for taking an unhealthy interest in grounding abstract physical concepts in the most widely accessible forms of reasoning and experience. Popularizations of this sentiment included Percy Bridgman's "operationalism," which influenced quantitative research methods in the social and psychological sciences, and Otto Neurath's universal picture language, "Isotype," which he envisaged as integral to workers' education in the promotion of socialism.

An interesting feature of the dispute between Karl Popper and Thomas Kuhn that would come to define much of the philosophy of science in the 1960s and 1970s is that both were involved in science education: Popper had taken a doctorate in educational psychology and began his academic career as a schoolteacher, while Kuhn's first post, which provided the backdrop to Kuhn (1970), involved teaching the history and philosophy of science to nonscience Harvard majors in a newly established "general education" program. Moreover, Popper's and Kuhn's understandings of scientific inquiry were strongly shaped by the two schools of experimental psychology – Gestalt and behaviorist – that were prominent in the middle third of the twentieth century. This led them to stress the broadly "constructed" character of scientific knowledge. But whereas Kuhn understood matters from the standpoint of those who inhabit the construction (i.e., the psychological subjects), Popper saw it from that of the construction's architect (i.e., the psychological experimenter). This led Kuhn to emphasize the relative difficulty and Popper the relative ease with which scientists can change their cognitive orientation. For Kuhn, science education instills a deep, perhaps even inviolable, commitment, while for Popper it provides no more than a convention whose value rests entirely on its consequences for inquiry (Fuller 2000, Chap. 6). Perhaps the most interesting twist that has been given to the constructionist approach by recent sociology of science has been Collins and Evans (2007), whose concept of "interactional expertise" is meant to capture how people not formally trained in a given science might learn enough simply by interacting with the relevant scientists to end up contributing productively to their work. It remains an open question whether this concept is better understood as an elaborate attempt for sociologists to gain the respect of scientists or an updated version of the project to democratize scientific knowledge originally championed by Mach.

Analytic Social Epistemology and the Socialization of Scientism

"Analytic social epistemology" refers to how social epistemology is practiced by the dominant school of contemporary academic philosophy (Fuller 2007). It has tended to interpret the problem of knowledge in science education as a matter of squaring the demands of truth, critical thinking, and trust in expertise. The juxtaposition of these concerns occurs against a presumed background tension between the norms of science and democracy. However, the relatively insular nature of this literature leads to some idiosyncratic framings of the issues that make it difficult for the tension to be expressed as such. "Truth" is typically understood via the doctrine of *veritism*, according to which a truth-oriented inquiry tracks reliable processes of knowledge production that inquirers may not be able to justify for themselves, in which case they may be rationally compelled to rely on the relevant experts. The question then is how to identify those experts. Depending on the students' cognitive development, they might assess competing arguments or turn to the arguers' track records, assuming that prior relevant cases to the one at hand are easily identified and are not themselves contested. Some of the feminist-inspired literature in this vein speaks of "epistemic injustice," which refers to people whose testimony is not trusted because of who they are rather than what they know (Fricker 1998).

As this brief description suggests, veritism fosters "epistemic paternalism" in the words of its leading proponent (Goldman 1999). Veritism's opponents point to a potential tradeoff between critical thinking and truth seeking: the former is valuable only insofar as it facilitates the latter. Yet, critical thinking is to an "Enlightenment" approach to education that would enable students to exercise intellectual autonomy, especially in response to classroom challenges to their default beliefs. This view, which harks back to John Dewey and entered analytic social epistemology through Israel Scheffler and his student Harvey Siegel (1988), gives pride of place to training the entire person to experience life in an inquiring frame of mind over simply ensuring that the student has acquired an epistemically prescribed set of beliefs (and the means required to access them). In the former case, science is simply a more technically specialized version of general life skills, whereas in the latter, "science" refers to the class of experts to whose judgment one should defer under the relevant conditions.

An interesting consequence of veritism's hold over analytic social epistemology is its transformation of the concept of *scientism*. In its original late nineteenth-century incarnation, scientism was a rather diffuse movement inspired by Auguste Comte's attempt to turn modern science into a new "world religion," one modeled on Christendom that would penetrate every aspect of people's lives while providing a universal basis for social cohesion. Although Comte called his movement "positivism," one might also include Marx's dialectical materialism in this development (Frank 1949). However, the most self-consciously active form of scientism was *monism*, whose German standard-bearers, the embryologist Ernst Haeckel and the chemist Wilhelm Ostwald, set precedents for promoting science as a total worldview in the twentieth century – Haeckel on Darwinian evolution and Ostwald on thermodynamics (aka "energeticism"). In each case, some sense that spirit "emerges" from a material complex meant that science could absorb rather than simply annihilate religion. In that sense, contra Max Weber, science could "re-enchant the world," so that, say, eugenics or energy efficiency might serve as the personal ethics corresponding to general scientific principles (Fuller 2006, Chap. 5). While the dawn of the twenty-first century appears to have reinvented this line of thought in, say, Richard Dawkins and James Lovelock, the doctrine that is nowadays both defended and attacked under the rubric of "scientism" does *not* normally refer to it. Rather, in the paternalistic spirit of veritism, "scientism" nowadays refers much more simply to deference to whatever "scientific consensus" obtains on policy-specific issues. In other words, for the analytic social epistemologist, science aims to replace not religious belief but democratic decision-making (Ladyman et al. 2007).

Cross-References

- ▶ Epistemology
- ▶ History of Science
- ▶ Science Studies
- ▶ Sociology of Science

References

Collins H, Evans R (2007) Rethinking expertise. Chicago University Press, Chicago

Frank P (1949) Modern science and its philosophy. Harvard University Press, Cambridge

Fricker M (1998) Epistemic injustice. Oxford University Press, Oxford

Fuller S (1988) Social Epistemology. Indiana University Press, Bloomington

Fuller S (2000) Thomas Kuhn: a philosophical history for our times. Chicago University Press, Chicago

Fuller S (2006) The philosophy of science and technology studies. Routledge, London

Fuller S (2007) The knowledge book: key concepts in philosophy, science and culture. McGill-Queens University Press, Montreal

Fuller S (2009) The sociology of intellectual life. Sage, London

Goldman A (1999) Knowledge in a social world. Oxford University Press, Oxford

Kuhn T (1970) The structure of scientific revolutions (Orig. 1962). Chicago University Press, Chicago

Ladyman J, Ross D, Spurrett D (2007) Every thing must go: metaphysics naturalized. Oxford University Press, Oxford

Siegel H (1988) Educating reason. Routledge, London

Social Media

▶ Social Networking

Social Networking

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Keywords

Facebook; Social media

Introduction

Technological advancements have contributed increasingly to young people's adoption of social media, a term often used interchangeably with Web 2.0 to refer to online applications which promote users, their interconnections, and user-generated content.

Social networking sites like Facebook and LinkedIn are a form of social media widely adopted among adolescents and college-age youth as a dominant technology-mediated leisure-time activity. Social networking sites are defined by the following socio-technical features: (1) uniquely identifiable profiles that consist of user-supplied content and/or system-provided data, (2) (semi) public display of connections that can be traversed by others, and (3) features that allow users to consume, produce, and/or interact with user-generated content provided by their connections on the site. Social networking sites are distinguished from other forms of social media, like wikis, by the emphasis they place on personal profiling features and interactions with other users' profiles and their shared content (e.g., text, hyperlinks, videos).

Social networking sites are used predominantly to connect with those one already knows and less for traditional networking purposes, but sites such as LinkedIn are designed explicitly for building one's list of personal contacts. Thus, social networking sites are Web-based services through which individuals can maintain existing ties and develop new social ties with people outside their network.

Social Networking in Education

Social networking can be integrated into educational practices in elementary and secondary school classrooms, higher education, and informal learning settings. Research on the use of social networking sites in education has focused on its use by students, especially college students, within a particular course, but less on uses for informal learning. Young people use social networking sites for a wide range of purposes, some of which are educational in nature. Learners can make use of their existing online socializing practices, leveraging their social networks for learning functions in direct and indirect support of education-related tasks and values. These social learning functions can include (1) obtaining recognition for and appreciation of creative work through feedback on their profile pages and (2) reaching out to former classmates to give or receive help in managing the ups and downs of high school or college life or even direct help with school-related tasks (Greenhow and Robelia 2009). Selwyn (2009) describes how students' education-related uses of the social networking site Facebook also included post hoc critiquing of learning experiences and events, exchange of logistical or factual information about teaching and assessment requirements, and instances of supplication and moral support concerning assessment or learning.

Clearly, the application of social networking for educational purposes poses some challenges. Kirschner and Karpinski (2010), for instance, found a negative relationship between time spent on Facebook and college grades. More recent research suggests that the manner in which social networking is used makes a difference in whether academic outcomes are positive or negative (e.g., Junco 2012). For example, posting status updates and chatting on Facebook were negatively predictive of GPA, while sharing links were positively predictive. Interacting with fellow students around curricular content or other learning-related topics may be expected to be positively associated with achievement but also with one's engagement in a practice- or interest-driven learning community.

Science Education

At the time of this writing, there are few published empirical studies on the use of social networking in science education. However, social networking in education generally can facilitate new forms of collaborative knowledge construction, communication, identity work, social capital, and civic participation, both online and offline. For instance, social networking can stimulate social benefits, online and offline, which can have implications for education. Social capital refers to resources or benefits available to people through their social interactions and is valuable to feelings of trust, reciprocity, and social cohesion. Researchers have found positive associations between students' use of their dominant social networking site (e.g., Facebook or MySpace) and both bonding and bridging social capital (Greenhow and Burton 2011). Students have reported that social networking is often part of their learning and high school-to-college transition strategy (Greenhow and Robelia 2009a, b).

Social networking can also enable innovative forms of peer collaboration (Zhang et al. 2009). In studying elementary school students within a formal classroom setting, Zhang et al. (2009) found that social networks within Knowledge Forum provided opportunities for students to connect to a broader network of peers and their ideas than they might have otherwise. This facilitated collective responsibility for the learning of the group and dynamic knowledge advancement over time through flexible, opportunistic collaborations, which in turn served to increase the possibility of diverse spontaneous inquiries, flexible participation from group members, and transparency. In particular, participants could see ideas taken up and modified by the group, which helped students grasp an overarching vision of the changing status of their community knowledge and the interactions taking place at the community level.

Collaboration and coordination among a range of participants may be facilitated by the following features typically present in social networking sites: (1) a nonhierarchical structure, where learners have ownership of and can contribute to a public or semipublic space; (2) the ability to asynchronously coproduce content; (3) automatic publishing capabilities; (4) the ability to adapt the layout or functionality of the environment; and (5) the ability to enable geographically distributed, opportunistic, flexible, and dynamic social arrangements rather than centralized or fixed arrangements.

Thus, social networking can play a valuable role in increasing the diversity of idea sharing and facilitating the cooperative or collaborative engagement of teachers, students, and others in the learning process. Students can use social media to provide feedback and support to peers and also share work with an audience beyond their teacher. Connections can be made with teachers, peers, or even students at other levels of education, across different physical locations, and outside specified class times and with the wider community.

In science education specifically, social networking applications can serve to increase students' interest in science-related issues. For instance, Greenhow and colleagues designed an educational application within Facebook called Hot Dish to allow users to post climate change news stories and comment on them as well as complete "eco-friendly" civic engagement activities, both online and offline in their local communities. Located as a tab within one's existing Facebook profile, the key features of Hot Dish included the ability to post original story entries; share articles from online sources; browse or read articles; curate, rank, and comment on posted entries; craft a personal profile; showcase users' statistics and contributions; and participate in Action Team challenges both online and offline (e.g., writing a letter to the editor, signing an online petition, volunteering for an environmental organization, recycling). The research team found that peer role modeling on this site motivated pro-environmental behaviors as well as argumentation about socio-scientific issues (Greenhow and Li 2013).

Applications like Hot Dish show that social networking features can facilitate information sharing about science issues, commentary and debate, and the completion of problem-solving challenges, activities that engage users in activism around those issues. Similar to gaming environments, users can earn points for completing offline challenges, which acknowledge individuals for offline behavior (e.g., environmental activism) and motivate others in the online environment to make their own behavioral changes. Similar data-tracking and representational features could be built into future science education environments to foster targeted learning (and teaching) behaviors, role modeling, or civic engagement.

Cross-References

- ▶ Blogs for Learning
- ▶ Knowledge-Building Communities
- ▶ Web 2.0 Resources for Science Education

References

Greenhow C, Burton L (2011) Help from friends: social capital in the social network sites of low-income high school students. J Educ Comput Res 44(4)

Greenhow C, Li J (2013) Like, comment, share: collaboration and civic engagement in social network sites. In: Mouza C, Lavigne N (eds) Emerging technologies for the classroom: a learning sciences perspective. Springer, New York, pp 127–241

Greenhow C, Robelia B (2009a) Old communication, new literacies: social network sites as social learning resources. J Comput Mediat Commun 14(4):1130–1161

Greenhow C, Robelia B (2009b) Informal learning and identity formation in online social networks. Learn Media Technol 34(2):119–140

Junco R (2012) Too much face and not enough books: the relationship between multiple indices of Facebook use and academic performance. Comput Human Behav 28:187–198

Kirschner AP, Karpinski AC (2010) Facebook and academic performance. Comput Human Behav 26:1237–1245

Selwyn N (2009) Faceworking: exploring students' education-related use of Facebook. Learn Media Technol 34:157–174

Zhang J, Scardamalia M, Reeve R, Messina R (2009) Designs for collective cognitive responsibility in knowledge-building communities. J Learn Sci 18:7–14

Social Studies Education and Science Education

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Keywords

Citizenship; Science literacy; Social action; Social studies; STSE science education

Consider voting on a proposal to build a sewage treatment facility to deal with the sewage currently dropped untreated into a nearby body of water when the costs of construction and maintenance of the facility require an increase in taxes. In order to make an informed decision, voters would need enough science background to understand studies of the risk posed by the sewage to the water ecosystem, a good sense of what constitutes a valid scientific study, and a basic understanding of the potential and limits of the facility engineering and technology. This type of science-related knowledge and understanding is called "science literacy," and since the 1970s achieving the scientific literacy needed for active engagement in such personal and societal decision-making has become a fundamental goal of modern school science curricula. This approach to science was called "STS" (science-technology-society) (Yager 1996) or STSE when it included environmental studies. In the 1980s, the STSE approach was incorporated into the "Science for All" or "Public Understanding of Science" movements; a key feature of these movements was an emphasis on social action in and through science education (Hodson 1988).

However, STSE struggled to gain a foothold in schools, due to a number of complex factors. One was the inability of science to understand what is actually involved in effective political action and the history of social change. For example, to vote on the sewage treatment plant, citizens also need to understand economics, dynamics of local governance, geopolitical issues around locating the facility, and the possibilities for civic engagement. In schools these topics, in various incarnations, are generally the focus and territory of the school subject/curriculum area known as "Social Studies."

Parallel Developments of Science and Social Studies as School Subjects

Social Studies and Science as school curriculum areas each represent amalgams of different fields of study. General science, for example, typically includes physics, chemistry, biology, and Earth science; all fields of study concerned with the natural world. Social Studies includes a range of fields of study in the social sciences, such as history, sociology, geography, and civics, that are aspects of studies of the social world of human societies at various levels, times, and functions.

Social Studies came into being as part of the late nineteenth century humanitarianism movement that, in the early twentieth century, was adopted by progressive educators such as John Dewey. The key goal of the school subject "Social Studies" was the development of students' abilities to engage in social progress though democratic renewal. Dewey recognized that this development would not be effective unless taught in partnership with the skills and understanding achieved through interdisciplinary studies that include science and mathematics.

In the first half of the twentieth century, each school subject was continually challenged as a superficial merging of fields of inquiry that deserved their own subject status if students were to understand the underlying ideas and structure of each discipline. This was particularly true with History but also applied to arguments for an early cleaving of school science into the separate subjects of Biology, Chemistry, and Physics (Goodson 1987). Discussions concerned about what constituted a valid Social Studies or Science Education were further complicated by those advocating separate subjects of study in schools that seems to embody aspects of both Social Studies and Science, such as Geography and, in the second half of the twentieth century, Environmental Studies. The debate over what constitutes a valid study of nature or of society was also affected by the two World Wars that punctuated the history of the twentieth century. In science, the World Wars demonstrated the importance of technological innovation and the need for students to choose careers in science, technology, and engineering, while in Social Studies instruction in ethics and civic responsibility were seen as ways to work toward peace through the education of the next generation.

These complex, generative curriculum discussions were refocused in the industrialized Western world by the launching in 1957 of the first human-made satellite, Sputnik by the former Soviet Union. The effect of this event on science education curriculum reform in North America is well documented. What is less often recognized is that Social Studies as well went through a similar reform process approximately a decade later, becoming what was called the "new Social Studies." While science education moved toward a more technical, facts-based approach to science that emphasized the structures of science disciplines, Social Studies initially moved toward developing interdisciplinary studies that explored the "shared humanity" believed to be part of all social systems. The "new Social Studies" did not fare well as many (including parents, educators, and scholars) insisted on a return of the traditional Social Studies topics of national history, world history, civics, and government. Science curriculum reform initially seemed to be more successful, likely due to massive support by governments and the scientific community. However, by the mid-1970s, it was clear that science education was also in crisis; despite a clear goal of attracting men and women to a career in science, engineering, and technology, the new curricula and associated pedagogies were having the opposite effect.

Science and Social Studies: Interdisciplinary Partners for Social Action

STSE science education was, in part, an effort to redirect science education curriculum reform toward a more socially relevant approach to science education and, hopefully, attract more students to science-related careers. But STSE did not emerge as the major approach to science education in the world. Part of this was due to the development of international testing systems, such as initially TIMSS and then from the beginning of this century PISA, and outcomes-based curriculum development, both of which favor curricula emphasizing scientific content knowledge. In addition the development of a more conservative and economically competitive world, political climate moving into the twenty-first century has had similar impact. A key issue in the lack of adoption of STSE science education was the inability of this approach to science to adequately conceptualize the form, appearance, and direction of social action for students; that aspect of education was assumed to be the responsibility of Social Studies.

The separation of the two subject areas is today more acute and problematic than ever. As human populations continue to expand, citizens increasingly face difficult decisions about issues such as disposal of garbage and sewage, traffic control, homelessness, and continued urbanization. Many of these issues are linked to and affected by broader, global dilemmas humankind collectively faces in the twenty-first century, such as global climate change due to increased use of fossil fuels; trying to find ways to feed, clothe, and employ an increasing human population; the appearance of antibiotic-resistant strains of infectious diseases; and loss of biodiversity – as well as an expanding pollution of sources of freshwater and ocean habitats. As well, discoveries in science and technological innovations, such as the development of non-decomposing plastics, genetic engineering, and humanoid robots demand an increased public debate and involvement in the directions of science, engineering, and technology.

School science education can provide a foundation for students to acquire the literacy to understand the key science of these issues, but remains barren in the expertise to assist student development of effective avenues of social action. Social Studies, with a large repertoire of interdisciplinary understanding of the history of societies and how governments operate, can inform science students about methods of social engagement but is somewhat barren, except perhaps in providing a historical perspective, on the science knowledge needed to fully understand current and future issues arising from science discoveries and technological innovation.

Recent efforts to reconceptualize science education as a merging of science, technology, engineering, and mathematics (STEM) and STSE, and a rise in the discussion of values in science education (Corrigan et al. 2007) as well as what might constitute a “citizen science” education (Roth and Barton 2004) may yet serve to foster a more socially engaged science education while also inviting students to consider careers in science, technology, and engineering. But this reform still needs to form a school subject partnership with Social Studies to make progress toward Dewey’s vision of education as a vehicle of democratic renewal. The development of the Internet and social media in the twenty-first century may prove to be the most important technological innovations in this direction. While some argue that it is too large a challenge for the average citizen to think of their responsibilities outside their immediate social situation and geographical locale, there is emerging evidence that youth with access to social media, news media, and the Internet already see themselves as “citizens of the world.” Their global perspective presents an important and timely opportunity for the education of students as local and global citizens, aware of their civic responsibility and able to engage with their peers and others in a democratic, planetary discourse when dealing with urgent issues that cross borders, such as water pollution, climate change, loss of topsoil, and the continued development of technologies of destruction. As well, we look to this generation for the development of new, hopeful technologies that can feed and clothe the growing population and the scientific discoveries that enable a reengineering of societies toward sustainable practices that benefit all species on the planet. These are demanding expectations and to rise to challenge students need a generative, interdisciplinary education, especially issue-focused partnerships between Science and Social Studies.

Cross-References

- ▶ Context-Led Science Projects
- ▶ Curriculum and Values
- ▶ Dewey and the Learning of Science
- ▶ Ecojustice Pedagogy
- ▶ Environmental Education and Science Education
- ▶ Public Understanding of Science
- ▶ Relevance
- ▶ Science for All
- ▶ Science for Citizenship
- ▶ Science, Technology and Society (STS)
- ▶ Sustainability and Science Education
- ▶ Technology Education and Science Education
- ▶ Values and Western Science Knowledge

References

Corrigan D, Dillon J, Gunstone R (eds) (2007) The re-emergence of values in science education. Sense Publishers, Rotterdam

Goodson I (1987) School subjects and curriculum change. Falmer Press, New York

Hodson D (1988) Teaching and learning science. Open University Press, Philadelphia

Roth M, Barton A (2004) Rethinking science literacy. Routledge/Falmer, New York

Yager R (1996) Science/technology/society: as reform in science education. State University of New York Press, Albany

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Socio-Cultural Perspectives and Characteristics

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Keywords

Ecological consciousness; Indigenous knowledge systems; Ontological relativism; Sciences of all; Sociocultural; Social constructionism; Worldview

During the closing decades of the twentieth century, science education researchers embraced personal construct theory and explored the many interesting ways in which students develop "misconceptions" of the natural world which differ significantly from the canonical scientific view. Pedagogical strategies were developed to enable teachers to detect and remedy these intuitive ways of making sense of everyday experience or, for most students, of the canonical representations contained in the artificial world of the science textbook. The later arrival of social constructivist theory emphasized the crucial role of negotiation and consensus in making sense collectively of personal experience. This resulted in more discursive learning environments in which students negotiate their developing canonical understandings. Science curricula and pedagogies shaped by constructivism and related theories, such as socially situated cognition, continue to work well in assimilating students into the canonical scientific worldview, which was born in the eighteenth-century Age of Enlightenment and has given rise to today's political imperative of *science for all*.

At the same time, however, a political awakening was taking place among science educators with a strong social conscience and a deepening concern about how science and technology are implicated in global crises, such as climate change, that are threatening the well-being of humanity and the planet's ability to sustain all forms of life. These radicalized researchers shifted their attention away from the dominant psychological focus on cognitive activity and embraced sociologically inspired investigations of the cultural relevance of science curricula to peoples worldwide. Researchers reached into other disciplines – philosophy, linguistics, anthropology, politics, and sociology – and adopted powerful sociocultural perspectives to explore critically the history, philosophy, and culture of science and science education.

Most sociocultural theories are underpinned by the *ontological relativism* of social constructionism (e.g., Berger and Luckmann 1966) which holds that explanations of the world are culturally and historically contingent. In other words, none of our explanations necessarily reveal the essence of "things in themselves"; instead, ideas, concepts, and theories are social constructs which are transformable. This transformative perspective applies to scientific knowledge of both the natural world and the social world. In the latter case, social activists are emboldened to transform seemingly natural attitudes and social actions that they perceive instead as cultural products. The rise of qualitative social science research paradigms – *interpretivism*, *criticalism*, *and postmodernism* – has greatly facilitated these transformative inquiries and interventions.

One of the first notable interventions in science education was conducted by critical feminist researchers who identified gender as a social construct rather than an inevitable result of biology. From this perspective, feminist scholars revealed and contested the implicit masculinist culture of science education, especially its girl-unfriendly representations of science in textbooks. Their research demonstrated how a dominant masculine culture had served as a barrier to girls' participation and achievement in science and to their subsequent selection of science-related careers. The result of this research has been the development of gender inclusive science curricula and pedagogies; in many countries, girls are now outperforming boys in science and mathematics.

As science educators reached further afield, they encountered a range of sociocultural theorists whose powerful ideas have continued to challenge us to radically rethink the fundamentals of science and science education. The following is a small sample of the best known:

- The German Frankfurt School yielded Jurgen Habermas' theories of *communicative action* and *knowledge constitutive interests*, which have helped to identify disempowering ideologies embedded in the social fabric of educational policies, science curricula, and pedagogies and have brought a moral/ethical perspective to considerations of what constitutes emancipatory social relationships in the science classroom.
- Notable among the French *poststructuralist* and *postmodern* philosophers are Jacques Derrida, Pierre Bourdieu, Gille Deleuze, and Michel Foucault whose sociocultural theories have fuelled deconstruction of the sociological foundations of education systems and institutions, of which science education is an integral part, revealing otherwise invisible economic, political, historical, and cultural assumptions and identifying whose (human) interests are not being well served.
- From Russia, Aleksei Leontiev's and Lev Vygotsky's *culture-historic activity theory* provides a framework for analyzing the dialectical relationship between social activities of individual actors (e.g., teachers, students) and the social structure of the organization in which they are embedded (science classroom, school, society). This social constructionist perspective also focuses on the mediation role of language in constructing meaningful ideas, with implications for the role of the child's "mother tongue" in the science classroom.
- From the UK, *sociology of scientific knowledge* (*ssk*) *theorists*, especially David Bloor and Harry Collins, have drawn on the work of Thomas Kuhn, cultural anthropologists, and linguists such as Wittgenstein to portray science as "shot though" with social influences and scientific knowledge as socially contingent; good news for cultural relativists who advocate an inclusive "sciences of all" curricular standpoint.
- From various nations at the leading edge of political decolonization movements of the twentieth century, the *postcolonial theorizing* of Paulo Freire, Frantz Fanon, Gayatri Spivak, Edward Said, and Homi Bhabha has fuelled cultural studies researchers' endeavors to neutralize the dominance of the Western modern worldview in science curricula and research, particularly for minority youth in Western countries and majority youth in recently independent nation states (with a special focus on indigenous people).

Sociocultural perspectives constructed from these sources (and elsewhere) are providing renewed impetus to *worldview* research conducted in the early 1990s by science educators such as Bill Cobern. Contemporary culture studies researchers are documenting indigenous knowledge systems (IKS; also known as traditional ecological knowledge (TEK) and funds of knowledge) embedded in traditional community practices of indigenous peoples worldwide. This research is enriching the fields of ethnoscience/mathematics established mid-twentieth century by researchers such as Ubiratan D'Ambrosio. For some time, culture studies researchers have been considering the thorny question of how to reconcile the tension between Western canonical science and indigenous knowledge in order to include IKS as a legitimate part of standard science curricula; the debate is ongoing. Leading culture studies science education researchers include Glen Aikenhead (Canada), Masakata Ogawa and Ken Kawasaki (Japan), Liz McKinley (New Zealand), M. B.Ogunniyi (South Africa), and Greg Cajete (Mexico).

Research employing sociocultural perspectives is transforming our understanding of science and science education and is enabling us to grasp the moral and ethical need for a *socially responsible* science education that prepares future generations with the knowledge and skills to resolve the legacy of global crises, especially loss of biocultural diversity. Indigenous researchers influenced by sociocultural perspectives are conducting studies of their local communities and designing culturally contextualized science curricula to contribute to young indigenous people embracing modern science while also learning deeply about and respecting their own indigenous knowledge, cultural identities, languages, and community practices (e.g., Aikenhead and Michell 2012; Afonso Nhalevilo 2013). By drawing on cultural traditions that honor the connectedness of people and the natural world, it is believed that indigenous knowledge systems will be a source of authentic *ecological consciousness* that can help to revive our sense of stewardship of the planet.

Dedicated journals such as *Cultural Studies of Science Education* and special issues of journals such as the *International Journal of Science and Mathematics Education* (Abrams et al. 2013) are important means for legitimating and disseminating this innovative research.

Sociocultural perspectives have helped us realize the pressing moral and ethical need to complement our endeavors to deliver *science for all* with well-researched curriculum perspectives on *the sciences of all*.

Cross-References

- ► Socio-Cultural Perspectives on Learning Science
- ► Teaching and Sociocultural Perspectives

References

Abrams E, Taylor PC, Guo CJ (eds) (2013) Forward: teaching and learning of science for Indigenous learners. Int J Sci Math Educ *11*(1), 1–21

Afonso Nhalevilo E de F (2013) Rethinking the history of inclusion of IKS in school curricula: endeavoring to legitimate the subject. Int J Sci Math Educ *11*(1), 23–42

Aikenhead G, Michell H (2012) Bridging cultures: indigenous and scientific ways of knowing nature. Pearson Education Canada, Toronto

Berger PL, Luckmann T (1966) The social construction of reality: a treatise in the sociology of knowledge. Anchor Books, Garden City

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Sociocultural Perspectives and Gender

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Keywords

Culture; Science education

A sociocultural perspective of science education infers that there is a dialectical relationship between cultural production and creation. Cultural production involves an actor's agency and engagement with schema. When cultural creation is passive, that is, an actor is not actively engaged with culture. When culture is enacted, actors are dialectically involved at both individual and collective levels with cultural enactment in social fields (Tobin 2012). Within a social field, an actor's identity is a combination of one's own construction of self along with how one is constructed by others. Thus, identity is simultaneously fixed and changing.

Gender is a social category and as such structures any social interactions, including those that constitute schooling and science education. As a social category, gender is constituted on the *structural*, the *symbolic*, and the *individual* levels in society. The *structural level* examines how gender influences the organization of society (Harding 1986), for example, examining the division of labor by gender. In science, there is a consistent pattern of more women working in the biological sciences compared to the physical sciences. The biological sciences are perceived as having stronger connections to humans and other living things compared with the focus in physical sciences on innate objects. The former being more feminine and the latter masculine is one explanation for this gendered pattern. The *symbolic* level of gender uses dichotomies where the oppositional pairs are assigned a feminine and masculine meaning (e.g., nature/culture, emotion/rationality, subjectivity/objectivity) that infers what are appropriate practices for women and men. For example, the symbolic level describes science as rational, difficult, and hard, with disembodied knowledge. Thus, both structurally and symbolically, science is a masculine gender practice. In contrast, teaching, especially children, is described as nurturing and caring, which is symbolically feminine. Gender at the *individual* level is influenced by structural and symbolic levels. However, a person's agency can change or modify one's identity based on gender because the levels exist in a dialectic that can impact and transform *structural* and *symbolic* gender. Participants' gendered identities are differentiated in different cultural fields. And one's gender is a major construct on how others construct our identity (Scantlebury 2012).

Typically, science educators use gender of the individual rather than a social context. And as such, gender is often conceptualized as a dichotomy of girls/women/boys/men with the associated descriptors for feminine and masculine traits. There is a lack of *knowledge about gender* in science education research. Many of the studies do not offer a critique of the "gender" concept but focus on comparing female and male students on variables such as achievement, participation, engagement, and attitudes toward science. Butler (1990) challenged the notion of gender by conceptualizing it as performative, and within this framework the research should focus on the intersections between gender, sex, and sexuality. However, science education research has not embraced that the term "gender" is broader than feminine and masculine nor has the field engaged in a critique of the heteronormative language and practices used in science teaching and curriculum materials (Scantlebury 2012).

Moreover, while it is important to consider how gender impacts at the individual, symbolic, and structural levels, feminist researchers view intersectionality as a critical analytical tool to examine how overlapping social categories such as gender/sex/sexuality, race, social class, language, religion, etc., impact a person's identity and also social categories at the symbolic and structural levels. A crucial aspect of *intersectionality* is to view the interplay between different social categories that are unbounded and intertwined and examines society's power hierarchies and differentials (Lykke 2010). This interplay of gender with other social categories can impact and influence participants' achievements and attitudes in science and science education, science pathways and experiences in education, and informal science experiences.

Calabrese Barton (2008) suggested that science educators could utilize the concepts of intersectionality, counterknowledge, and solidarity to define critical science agency. Counterknowledge foregrounds the knowledge and experiences of those who have lived on society's margins, and solidarity reflects how a collective can become agentic to change social structures (e.g., women's involvement with ecological feminism to improve living conditions for their families). Currently, many science educators use gender as a category when often their analysis is based upon girls/women/boys/men (i.e., biological) differences. In order to understand the increasingly complex social fields within science as culture, we should engage with poststructuralist perspectives on gender.

Cross-References

- ▶ Socio-Cultural Perspectives on Learning Science
- ▶ Teaching and Sociocultural Perspectives

References

Butler J (1990) Gender trouble. New York: Routledge
Calabrese Barton A (2008) Feminisms and a world not yet: science with and for social justice. In: Roth W-M, Tobin K (eds) World of science education: North America. Sense Publishers, Rotterdam, pp 409–426
Harding S (1986) The science question in feminism. Cornell University Press, Ithaca
Lykke N (2010) A guide to intersectional theory methodology, and writing. Routledge, London
Scantlebury K (2012) Still part of the conversation: gender issues in science education. In: Fraser B, Tobin K, McRobbie C (eds) Second international handbook of science education. Springer, New York, pp 499–512
Tobin K (2012) Sociocultural perspectives on science education. In: Fraser B, Tobin K, McRobbie C (eds) Second international handbook of science education. Springer, New York, pp 3–18

Socio-Cultural Perspectives on Learning Science

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Keywords

Activity theory; Bakhtin; Contradiction; Culture; Dialectics; Vygotsky

Introduction

Sociocultural is an adjective that tends to be used in the Anglo-Saxon scholarly literature when research refers to and employs a range of concepts that have emerged in the particular domain of social psychology developed in the former USSR. Most fundamentally, the adjective is used to denote an epistemology that – in its original conception – uses society, culture, and history as the defining characteristics of human beings. It is also used to refer to a broad, internally highly differentiated movement with very different interests and approaches. The founder of this social psychology was Lev S. Vygotsky (1896–1934), sometimes referred to as the Mozart of psychology. After his premature death, Vygotsky's collaborators and students continued to elaborate and develop this form of psychology. Recent theoretical approaches in this perspective also include in their intellectual heritage the literary theorist and philosopher Mikhail M. Bakhtin (1895–1975) and his circle (V. N. Vološinov, Medvedev) (Depending on the language into which the works of these scholars are translated, alternative spellings of Vygotsky's Russian name (Rus. Выготский) include Vygotski (Fr., Sp.), Vygotskij (ling., Ital.) and Wygotski (Ger., Pol.); the name Bakhtin (Rus. Бахтин), depending on language, also is spelled Bachtin (Ger., Pol., Ital.), Bakhtine (Fr.), and Bajtín (Sp)). The Anglo-Saxon use of the adjective "sociocultural" actually is the result of an unfortunate, and likely politically motivated, choice to substitute the original Russian (from Vygotsky) and German (from Karl Marx) equivalents of *societal* with the linguistically associated but conceptually different adjective *social*. Together with society, Vygotsky, and his students and followers, emphasized *history* so that a more appropriate rendering adjective, as this occurs in some other languages, would be *societal–historical* (or cultural–historical).

Society as the Determinant Factor of Specifically Human Characteristics

The *societal–historical* perspective is fundamentally grounded in Marx's insight that what is specifically human is based on the societal relations in which an individual has participated.

Thus, Vygotsky chose to explicitly refer to Marx when suggesting that all higher psychological functions first are *societal relations* before being *psychological functions* that can be attributed to an individual. More recent analyses show that these functions operate, for the first time, in a societal relation between people. Thus, the ways in which scientists orient each other to, and come to understand, images at work are the same ways in which infants and toddlers and their mothers employ when they begin to read books. From this perspective, personality is the totality of the societal relations that a person participates in, and is subject and subjected to, at any one point in time. From this perspective, therefore, inequities in science achievements between students from the working and under-classes – including those living in poverty or the homeless – and those growing up in the middle and upper classes become understandable in terms of societal issues. In the latter classes, parents tend to spend more time with their infants, toddlers, and children – reading with them about animals or taking them to zoos and science museums – than those from the former classes, where families often struggle simply to make ends meet and to satisfy their basic needs. Thus, despite the rhetoric that comes with such agendas as *No Child Left Behind* (USA), the existing inequities in a society with respect to scientific understandings reproduce themselves with the different kinds of societal relations that children and youth come to participate in. In the Russian source language of the theory, therefore, as well as in the languages that retain the adjective, the *societal*–historical approach lends itself to critique – highlighted especially by those continuing Vygotsky's tradition, including A. N. Leont'ev, S. L. Rubinstein, and, subsequently, K. Holzkamp and the Berlin Critical Psychology group. The originators of the societal–historical perspectives recognized that psychology fulfills an ideological function and, in so doing, serves interests that tend to be those of the middle (bourgeois) class. The adjective *societal* explicitly makes this critical dimension possible, whereas the adjective *social* does not imply inequalities that derive from societal structure. The alternative adjective works against the ideology of an egalitarian society in which every individual is said to have the same potential and opportunities. This critical dimension of the societal–historical approach continues to be of importance in German-speaking countries and Scandinavia; but it is lost when the adjective is substituted by "social."

Marx's insight that *society* is what determines specifically human characteristics is saliently exemplified in the work with deaf and blind children conducted by Meshcheryakov. This work shows that without interactions with others, these children existed in a vegetative state, without any "innate" intention to explore, as Piaget proposed would be the case, and who did not stand upright let alone walk. These children were not incapable (e.g., genetically/intellectually). They subsequently developed specifically human capacities, including not simply learning to use material tools (like a spoon to feed themselves) but being guided to reflect on (by means of their developing intellectual tools) the material tools as objects in their own right. Some of these children, initially found in a vegetative state, subsequently developed to the point that they became university professors. That is, their explorative intentions were not "natural" and innate but rather developed while participating in intentional activities with others and reflecting on the objects involved in the activity and on the activities as a whole.

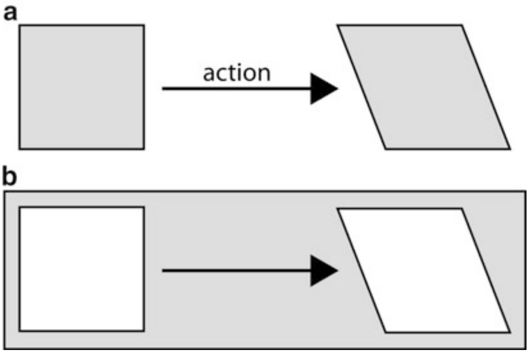
Unit Analysis Replaces Element Analysis

Theoretical Foundation

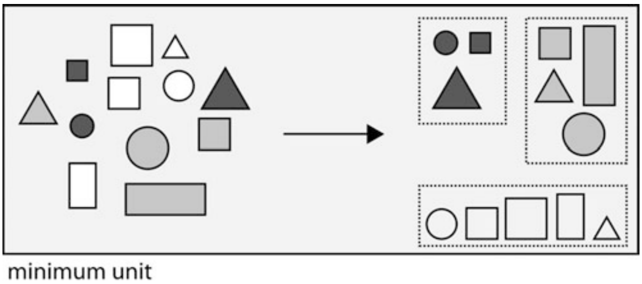
In the societal–historical approach, the unit of analysis shifts from the individual to the collective. Underlying the approach is the attempt to work against the reductionism of cognitivist and biological approaches to exploring learning. Vygotsky suggested that there are two types of analysis used in psychological research: analysis by means of decomposition of a whole into elements, comparable to the analysis of water in terms of the elements oxygen and hydrogen, and holistic analysis, equivalent to the analysis of water as hydrogen oxide. According to Vygotsky, the former is to blame for "all" the failures to understand psychological forms, whereas only the latter is the "correct" starting point for doing a first step in the direction of understanding the human psyche. Vygotsky metaphorically elaborated this contention by saying that to understand why water extinguishes fire, we need to look at the properties of water rather than at the properties of oxygen and hydrogen. When science educators research learning in terms of emotions, or beliefs, or mental frameworks, or conceptions, they reduce the complex human being to elements. This contrasts with the alternative approach that seeks to understand learning in the sciences from the fullness of (everyday) life. In the latter approach, learning in/of science is understood in terms of all the activities in which a person lives in the course of a day, week, month, or year rather than within a particular activity, such as the science classroom. *Perežįvanie* – which translates broadly as experience and feeling – is one such all-encompassing, irreducible unit that comprises the characteristics of the person, characteristics of the environment, and the temporal unfolding of both.

The following analogy is useful for distinguishing these two approaches, these two forms of analysis (Fig. 1). In this analogy, we model the shearing process that turns a rectangle into a parallelogram. In the common (reductionist) approach, complex phenomena are reduced to elements that are thought to be composing the phenomenon, and these elements are individually considered. Thus, in the example, the element is a square (e.g., representing prior science knowledge). A shearing force external to the square (a cause, e.g., representing an experience) acts upon the shape, changing it into a parallelogram (e.g., postexperience knowledge) (Fig. 1a). That is, there is an observable effect. The parallelogram is another element or, rather, the new shape (form) of a given material entity.

Unit analysis is different; because it is intended to capture change itself, unit analysis requires a minimum unit of *change*. This situation is represented in Fig. 1b. The entire situation including square, parallelogram, change, and time is all part of the minimum unit. In contradistinction to the preceding analysis in terms of elements, all of the square, the dynamic of change, and the parallelogram no longer can be conceived independently. These are taken as different ways in which the unit *manifests* itself. This unit would therefore focus on learning rather than on prior and post-unit knowledge. This also leads to the fact that there are no longer independent causes and effects, a characteristic of all process philosophies from Heraclitus to the present day: A cause is a cause because there is an effect, and there is an effect because there is a cause. This actually captures the observation that in the consideration of processes, we can attribute causes only after having observed something denoted as the effect. In science education research, a teaching method such as the use of analogies might be said to cause higher achievement or conceptual change. Yet in any particular case, a student from an experimental group (using analogies) might achieve less than a student from a control group (not using analogies). That is, whether a science curriculum is a causal force bringing about learning or conceptual change can be decided only after the fact, only after making the observation in any particular case.



Socio-Cultural Perspectives on Learning Science, Fig. 1 Element analysis versus unit analysis. **a** In element analysis the square is the unit, which, subjected to a shearing action (cause), is turned into a parallelogram (effect). **b** In unit analysis, the entire process of change is included in the minimal unit; beginning, end, and everything in between are constitutive parts of the whole



Socio-Cultural Perspectives on Learning Science, Fig. 2 Fundamental to the conceptualization of the socio-cultural approach is that it attempts to grasp change. The minimum unit of analysis therefore has to be one of change rather than one in which elements are subject to external forces

A Practical Example: Classifying

Classifying is one of the core scientific skills. The research literature shows that from as early as 2 years to being a mature scientist, doing science involves classifying objects and events. In the example of the classification of objects typical for a second-grade classroom shown in Fig. 2, the entire activity beginning with the pile of objects until the point of three ordered groups would constitute the minimum unit for a unit analysis approach. This inherently implies all the interactions between students, between students and their teachers, the particular division of labor that was enacted, the forms of participation and the particular rules that were practiced, and the means of production in use. Thus, for example, in the case of leaf classifications, we might consider making available field guides. The societal–historical perspectives then would lead us to anticipate that classifying leaves with and without field guides will change the outcomes. There are studies that exhibit the considerable differences in classification if the field guides employ photographs or drawings, the latter, against expectations, making classification easier than the former. Also, students might create resources for classification, such as a plastic bag with core examples of different categories of leaves. In this case, the activity transforms itself, as new tools are produced and, therefore, change the nature of the activity. As a result, we should expect very different outcomes with the use of technologies. Moreover, from these societal–historical perspectives, we should expect the observed outcomes of activities to change if students are tested in the absence of such tools.

Classification also will be different as a function of culture. This was quite explicit in research that Luria – a founder and leader of what sometimes is referred to as the *Vygotsky circle* – conducted with Kazakh peasants. Asked to sort skeins of wool by color, they refused and suggested this was an impossible task as all the colors differed. According to a Piagetian perspective on human development, these peasants were of lower cognitive capacity than most Western children. However, it turns out that the experience of attending school changed the ways in which these peasants would classify. That is, the cultural and historical (presence or absence of institutional forms of learning) mediates classification and, therefore, the outcomes of the testing activity. We should therefore not be surprised if children growing up in an aboriginal setting with strong focus on cultural heritage – e.g., in Australia, in New Zealand, in Hawaii, or on the Canadian and US Northwest coast – should engage in leaf classification and other science activities related to nature very differently than students in more urban areas and surrounded by more typical Western culture. We should expect that the schooling of science, as well as the schooling of traditional ecological knowledge, would change the ways in which students understand and, therefore, how they would learn and develop with respect to scientific knowledge.

Implications of Unit Analysis

Choosing a minimum unit (category) that is change itself leads to the position that change is the norm (e.g., learning, development) and stasis (knowledge, conceptual framework/structure) is the exception. Whereas in the classical case change (learning, development) is problematic, in the societal–historical approach, stasis is problematic (knowledge, conceptual framework/structure). Every time students engage in and with science, they change – though the nature of the change is not predetermined. For some students, a given science curriculum leads to learning and conceptual change; for others, however, even the best-designed curriculum might turn them away from pursuing a career related to science.

Within this perspective, society – its material and cultural aspects – is understood as a self-moving system. There are no outside (divine or other) forces that bring about the change. In the same way, there are no outside forces that change knowing and understanding. Participation in the activity of schooling, concretely realized in the science classroom, *is* change. There is no being outside of consciousness (knowledge) that makes consciousness develop, in the way that it might appear in constructivist approaches (i.e., a subject constructs its knowledge as if the subject could exist outside of its knowledge). Vygotsky explicitly critiques this latter approach that makes thoughts appear to think themselves.

Vygotsky's coworkers, students, and followers point out that society and its history constitute the relevant unit for thinking about knowing, learning, subjectivity, and personality. The smallest unit, therefore, has to be one that has all the characteristics of society as a whole. This unit, emphasized especially in that perspective referred to as cultural–historical *activity theory*, is an *activity*. Examples of activities include farming, manufacturing, and, pertinent to the present context, *schooling*. To understand what happens in science classrooms, therefore, the smallest unit would be that of schooling (rather than the student, or a group of students, or a teacher, or classroom, or school, and so on). There then exists a whole–part relation between this smallest unit and those aspects in which it manifests itself: school, classroom, teacher, students, curriculum materials, and so forth. Thus, we cannot understand the science student independent of the schooling the student is experiencing: the whole (i.e., schooling) requires students; and to be a student in the way this term is commonly understood requires the societal activity of schooling. Taking only one identifiable part changes the whole and, because of the change in the totality of relations existing within the whole, each part also changes. Drawing on Vygotsky's water analogy, if we take away the hydrogen from water, what remains is a different whole: oxygen. Its behavior and characteristics are very different from the preceding whole, which while it included hydrogen had no behavioral or characteristic similarities with either hydrogen or oxygen. Similarly, if we were to remove all students from schooling, what remains would not be schooling in the way we know it.

In the perspective presented here, material and intellectual tools play an important role. Most tools are used to change the material world. Intellectual tools come in the form of signs, including the various forms of inscription scientists' use and language. These allow humans, as Vygotsky explicitly noted, to control their brains from without. To understand language as a *living* phenomenon, we need precisely such a unit. Thus, language is alive when it changes every time it is used, every time someone articulates a word. A language is dead (classical Latin being one example), no longer changes, when it is not used.

Inner Contradiction

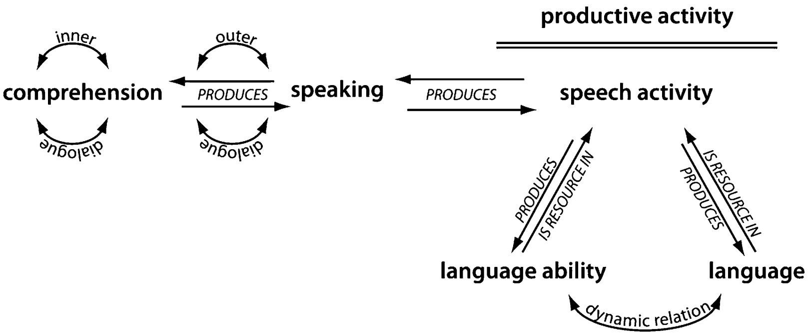
Contradiction is one of the most important categories in the formulation of the societal–cultural perspective on learning. This is immediately apparent when we consider the case depicted in Fig. 2 (and Fig. 1b). We can look at the unit and make one of two observations. These observations differ: the unit manifests itself in one or the other observation. That is, precisely because the minimum unit covers an activity from beginning to its end, we will make differing observations depending on the instant of time when we observe. There is a second way in which observations will differ: these depend also on where we look in the activity. We will make different observations when looking at one (e.g., a child) rather than another individual (another child, the teacher), at the materials (e.g., the after the first few objects being moved), at division of labor (which may change), and so on, even though all of these are part of the same unit (e.g., pereživanie). Classical logic suggests that these differences are the result of looking at different times or at different aspects (people) or the result of different people looking ("interpreting") at a situation. But Vygotsky's dialectical logic, which is based on taking a holistic perspective, suggests that the different manifestations are due to the *inner* difference *within* the unit considered – e.g., in Fig. 1b, the *unit* is a square and a parallelogram simultaneously – rather than *between* elements. Vygotsky explicitly rejects analysis by elements and suggests that only thinking in units will give proper theories of human learning and development.

A second form of *inner* contradiction exists in the fact that in societal–historical approaches, the material (physical) and ideal (mental) are theorized as two sides of the same phenomenon. What happens materially during a science laboratory experiment and the ways in which the events appear in consciousness are two manifestations of the same unit: the activity *as a whole*. Thus, children who classify the shapes in Fig. 2 not only do something materially but also find the material reality reflected in their consciousness and in their affect. Consciousness and affect are understood to be in a dialectical relationship, because each aspect is a manifestation of the current activity. These manifestations are not identical, though they are manifestations of the same (unit). Activities are characterized by their outcomes. Initially, these outcomes exist only on the ideal plane simultaneously with the reflection of the current material state. The participants in the activity orient to these anticipated outcomes. There is then an inner contradiction between the copresent reflection of the present state and the anticipated future state of the activity, the production process.

Dialogue and the Development of Speech and Language

To understand the dynamic nature of language, one has to theorize it as a moving phenomenon. Bakhtin and Vološinov therefore insisted that language changes every time that it is *used*, which always transforms the thing (e.g., Fig. 1b); moreover, they suggest for this reason that the word constitutes the same kind of dialectical unit. With every word or sentence usage, scientific language changes. This then explains how words, such as *atom*, come to be the same and different simultaneously not only from a historical perspective but also from the perspectives of individual development or that of language in a concretely unfolding situation. We can also understand the historically changing ways in the discursive organization of fields, for example, the changes from structure to function in the teaching of biology, or the changing ways in which an individual physics or chemistry teacher might talk about a certain topic from the beginning to the end of her career. The changes are not just changes in individual speech ability but changes in the language at large. Thus, Bakhtin provided a concrete analysis of the changing nature of the novel genre. He suggested that this change could not be understood if we aligned on some trajectory all the forms that the novel has taken historically. To achieve a coherent account, each novel had to be understood instead as a manifestation of current *general* culture and language. The changing nature of language, which occurs because mundane language is changing, leads to the different forms the novel takes. Every change of scientific language is a change in general language, which is the ground upon which any and all scientific languages are built.

Following Vygotsky and Bakhtin, who shared the conviction that dialogue is the origin of language, scholars working from this perspective tend to be very interested in the role of language in science learning. Pertaining to language, its use, comprehension, and development, everything is happening in real, affective–emotive societal relations where concrete speech activity



Socio-Cultural Perspectives on Learning Science, Fig. 3 Model of the relation between the different components in speaking and language

takes place (Fig. 3). Speech activity is subordinated to and constitutive of activity. Activity generates and drives speech activity, which, in turn, generates and drives societally motivated activity: There is a mutually constitutive relation. It is precisely here that we find the word, a phenomenon that integrates interlocutors: speakers and listeners.

Speech activity is concretely realized through speaking and replying, which is based on comprehension, including that of the speaker who comes to know his/her thought (after the fact) in the expressions used. Again, there is a mutually constitutive relation, as speaking concretely realizes speech activity but is produced in the service of the latter. In a conversation, there are interlocutors, who not merely externalize what is their own but who speak *for* the others using language that is not their own but has come to them from the other. Some science educators, therefore, suggest that “misconception” talk is inherently intelligible and shared: science educators understand this talk all the while knowing that it is different from the talk they intend students to use. To properly understand the phenomenon of speaking, it needs to be analyzed from the perspective of hearing, which implies comprehension. Comprehension itself is a dialogical process on the internal plane, and, in fact, all speaking has its genetic origin in *dialogical* speech. Thus, inner dialogue is the psychological reflection of outer dialogue, where it has its origin both at the cultural–historical (phylogenetic) and individual developmental (ontogenetic) levels (Fig. 3). The subjective reality of an *inner voice* is born in its *externalization* for the other. It therefore becomes what it is simultaneously for the other and the individual.

The generative role of speech activity *in societal relations* is shown in the model in Fig. 3 as the arrow from speech activity to language ability, whereby participation in the former is the origin of the latter. At the same time, language ability is a requisite in speech activity: the relation between the two is mutually constitutive. The same mutually constitutive relation exists between everyday speech activity and scientific language. Any change in everyday, scholarly, and aesthetic language emerges in and arises from common speech activity in societal relations, becoming a feature of language as a structured system. Simultaneously, there is always already a language that serves as a resource in scientific speech activity. As a result, we obtain a relation between individual language ability and the language of society. The relation between language as a societal phenomenon and language as a psychological phenomenon is a dynamic relation – and so is that of language as a system and language as a capacity. In terms of the perspective outlined here, speech activity is the category that sublates (overcomes and preserves) and therefore mediates between language as a system and language as a capacity, each of which is a (one-sided) manifestation of the overarching whole.

Thinking and Speaking

In the classical theoretical approaches from Aristotle to Augustine to present-day psychology, speech expresses on the outside what has been thought on the inside and, therefore, what is already represented in the structures of the mind (e.g., conceptions). In the societal–cultural approach, the relationship between speaking (the material dimension of an activity) and thinking (the ideal dimension of an activity) is much more complex. If we consider the situation of an individual student or teacher spontaneously speaking during a science class, then speaking and thinking are taken to be two related *processes*, each contributing to shaping the other, but neither taking precedence. In fact, the two processes are manifestations of one higher order process: *word signification* [Rus. *značenie slovo*] (Vygotsky) or theme [Rus. *tema*] (Vološinov). This overarching process makes it that the same word, even if spoken multiple times in the same unfolding situation, is never the same (never has the same function). Recent studies in science education – as those by Vygotsky and Bakhtin before – show that although there is a stable sound formation, intonation especially, in the articulation of a specific word, the placement of the same sound word changes how it is heard (semantics) and what it achieves (pragmatics). But what a science word achieves in any situation can be known only subsequently. Thus, individual speakers in spontaneous (science lecture) talk will find their thought in what they have actually said rather than expressing what has been thought out in all its details before speaking. Moreover, science education research has shown that language itself is a resource for articulating thoughts even when we have never had these thoughts before. Thus, when asked about some scientific phenomenon – e.g., distance, relative movement, and relative orientation of sun and earth – people respond even if they have never thought about it before. In fact, they may even say they have not thought of this before and still respond to the question. Thus, being familiar with sunrises and sunsets easily allows someone, a child or a Harvard graduate, with rudimentary language competencies to say that the sun moves – it rises in the morning and sets in the evening – rather than that the earth spins around its axis. Because of the everyday experience that the warmth experienced near a heat source changes with the distance to it, it is reasonable for someone to suggest that the earth is closer to sun in summer, especially if one has had no information to the contrary.

From this perspective, the word is not a property of the individual. Any word specifically, and language more generally, is a feature of culture and, by definition, impossible for one person. When a child talks about a phenomenon in a way that some science educators assert constitutes a “misconception,” this misconception is enabled by and exists in language. Even if a sound or other sign was to be created and used by a single individual – e.g., Einstein’s publication of the special theory of relativity – this would be based on the general practice of communicating by means of signs. Moreover, even when a sound word (science concept) is used for the first time, it implies the understanding of another. This is why other scientists could, for example, understand Priestley when he presented his ideas about “*dephlogisticated* air” (oxygen), even though the adjective had not existed before. Thus, with every sign initially used by one person also comes the possibility of general, shared use. Every idealization inherently implies reproducibility, both by the individual and other persons and, therefore, intersubjectivity.

Intellect and Affect

In the works of Vygotsky, Bakhtin, their students, and their followers, intellect and affect are theorized as two sides of the same coin. They are not independent, somehow *inter*acting elements that determine human behavior, as is conceptualized in most psychological theories. Piaget, for example, described affect as a sort of energy source (gasoline) to a motor (intellect) that does not change the structure of the motor. In the present perspective, on the other hand, intellect and affect are two sides of the same coin: different reflections of the same activity. This holistic conception of activity obviously also leads to the position that affect is not something that can be thought independent of intellect. According to Vygotsky, the separation of affect and intellect is the essential reason why traditional psychological theories fall short of understanding human behavior. This is so because there appears to be an autonomous stream of thoughts thinking ("constructing") themselves irrespective of the interests, motives, and impulses of the *whole* person. As recent research suggests, this means that to understand learning in the science classroom we need to look at the whole person, in the course of leading a life that includes but does not reduce itself to the science classroom. What we observe in the science classroom is a function of its place in a hierarchy of all the daily activities in which the person participates. This, as some studies in this field show, changes what we observe. If teaching physics is fourth in a list of importance for the teacher – following religion, family, and missionary activities – then what happens in and around the physics lessons will differ from observations we might make when teaching physics is the primary activity of the teacher.

From the perspective articulated here, affect and intellect are manifestations of the same activity. Affect is an indication of the difference between the current state of activity and its intended outcome. Being unable to progress through a science activity may be marked by both frustration (affect) and by the understanding that one is stuck (intellect). However, continuing with attempting to progress through the activity may lead to becoming "unstuck," which would be accompanied by more positive affect; on the other hand, not continuing is very unlikely to change the negative affective tone. Thus, even though both teacher and student might be frustrated about how far they are from understanding the task and each other, the only hope for getting closer to achieving their goals is to go on and to engage despite the frustration. Studies show that without this attempt to engage, there is no movement and students and teacher remain frustrated. With engagement, they can hope to get closer to the goal, which in turn tends to be reflected by more positive affect. Of course there is no guarantee that engagement leads to learning and more positive affect; quite the contrary, the parties involved might increase the distance to the intended goals of the science activities or come to understand that there are insurmountable barriers. In both situations, the tonality of affect will tend to be more negative.

Considering affect together with the expansion of action possibilities that emerge from cooperation with others leads us to understand two forms of learning: *expansive* and *defensive*. Expansive learning arises from the fact that in and through our participation, all of our action possibilities, our room to maneuver, and our control over conditions expand. Such expansion is inherently related to more positive affect. This might well explain why students often prefer working in groups. We engage in certain actions even though they may involve hardship when doing so increases our possibilities (e.g., success on an exam) once we are through the hard part (e.g., studying for an exam). Defensive learning denotes the situation where we engage in learning only to avoid sanctions (e.g., receiving a low grade, school suspension). It then becomes completely understandable that some students become perfect cheaters: To avoid low or failing grades, one can become good at a practice that avoids the real goal of the activity, knowing and understanding science, but still achieve the desired outcome (e.g., passing or high grade). When students do not accept the motive of activity, passing or high grade in science, then there is nothing teachers can do to motivate them: the students "don't care anymore." It is quite apparent that this societal–cultural perspective no longer requires us to operate with such concepts as individual motivation.

Learning and Development

One important aspect of the societal–historical approach that is often not well understood pertains to the distinction between learning and development. For Piaget, there existed two different processes, *assimilation*, in which new experience is associated to and understood in terms of existing mental schemas, and *accommodation*, a restructuring of mental schemas to make them appropriate for thinking about experiences that previously could not be understood. The two are very different, independent processes. For Vygotsky, on the other hand, learning and development are related; but learning, he insists, always precedes development. The two are related even though learning refers to a (quantitative) accretion of understanding and development to a qualitative change of understanding that is followed by a fundamental change in the forms of experiences that the person has. To understand this relation requires dialectical thinking, where, as developed by Marx, quantitative change leads to qualitative change. This change from quantitative to qualitative can be observed involving: (a) a particular form of initial understanding (conception); (b) objective changes in the environmental conditions that lead to a contradiction within the person; (c) the emergence of a new form of understanding (conception) existing *side-by-side with* the older type/s of experience; (d) change in dominance from the prior to the new form of understanding (conception); and (e) experiences in terms of the qualitatively new form of understanding (conception). Here, there are two qualitative changes: first, the emergence of a new form of understanding; and, second, the change in the nature of the dominant form of understanding. In this model, the older form of understanding (conception) is not eradicated, as some science educators have previously suggested has to occur in the case of misconceptions, but exists side by side with the older form of understanding (conception). This actually models quite well our everyday understanding that an astronomer can marvel at the beauty of a sun*rise* or sun*set*, a Ptolemean perspective, all the while using a Copernican perspective at work or while teaching astronomy. It has been shown that this societal–historical perspective can be modeled using catastrophe theory, a form of mathematics that combines quantitative and qualitative dimensions to explain the emergence of new forms (e.g., conceptions, talk), that is, morphogenesis.

An important concept that Vygotsky initially introduced to show how learning leads to development is that of the *zone of proximal development*. It was initially defined as the difference between a child's current cultural practices and those that it could enact in collaboration with a teacher or a more competent peer. The latter are said to *scaffold* the individual who is less competent at the task. For example, children in an early childhood science lesson may not arrive at the desired categorization of objects depicted in Fig. 2; they would be considered to be operating at one developmental level. But in the interaction with their teacher, they do achieve the categorization; in this societal context, they are operating at another developmental level. This change then precipitates operating at this more advanced level on their own because with the teacher they already operate at the higher level until they are in a situation to operate at this level on their own (similar to children learning to ride a bicycle by having adults first stabilize the bicycle until they can stabilize it themselves). In contrast to the nature-driven cognitive development in (Piagetian) constructivism, in the societal–historical approach development is mediated by culture.

In this example, the idea of the zone of proximal development is employed asymmetrically: metaphorically the teacher pulls the child to a higher level. However, new research in this perspective has shown that groups of equally capable students achieve *beyond* the developmental levels of any individual in the group. When children engage in the classification of objects such as depicted in Fig. 2, not only the product of activity but also the learning opportunities change if they work alone or in groupings with others, if they interact or not with the teacher. Moreover, recent STEM studies show that in groups with asymmetric experiences, even those to whom more initial knowledge is attributed learn from the group experience. Thus, for example, there are studies in science education showing that not only do science teachers continue to learn to teach while teaching (i.e., pedagogical content knowledge), also they learn and come to better understand the science content. That is, any time people work together in collectivities, that is, when they engage in societal relations with others, we can observe learning and development. Working in and as constitutive parts of collectivities leads to learning by expansion. It is likely for this reason that some scholars, such as Engeström and Holzkamp, have suggested alternative ways of understanding learning that occurs in relations with others. Thus, the zone of proximal development should be thought of in terms of the whole unit of analysis, which changes when a new form of activity is created in the collaboration of two or more individuals (cf. studies on coteaching science or studies on collaborative learning in the science classroom). As a result, there is a distance between current everyday actions and those possible in cooperation with others. In other words, the range of possibilities for individuals and their control over existing conditions increases in the cooperation with others for the purpose of achieving common, general goals; in this cooperation, any individual also increases control over individual conditions. Working with peers and teachers on the classification task (Fig. 2) in the societal activity of schooling not only expands what is collectively achieved but also what the individual can achieve, for example, the affective experiences that come from and with achievement.

Opportunities and Continuing Problems

The societal–historical perspective has proven to be of tremendous use for understanding and planning what happens in science classrooms. Most fundamentally, it shifts our attention from the individual to the collective (the group, class). With this shift, relations to others, language, and the all the material, cultural, and historical dimensions of the setting in which change and learning occur, all come to be made thematic. Despite the tremendous positive impact this perspective has had, there continue to be a range of problems. As science educators reading the works of Vygotsky, Leont'ev, Bakhtin, and other Russian scholars may note, there are sometimes tremendous differences in content and quality between the texts rendered in Russian and their native tongues and the English versions. This will not come as a surprise, as specialist scholars recognize the highly variable quality of translations into some Western languages. Some translations are more exact than others, that is, more in the spirit of the original Russian works. For example, the German and Italian versions of Vygotsky's *Thought and Language* are recognized to better represent what Vygotsky was writing and the spirit underlying his approach. The first English translation of this text omitted many crucial passages, and even the second, somewhat better translation has been criticized for leaving out materials or for incorrectly translating individual words and passages. It has almost completely changed the sense of what Vygotsky has written. The same is the case for the translations of Bakhtin and the members of his circle. Again, the English translations have been labeled as inferior to those that have been produced for other languages. One of the requirements for the continued evolving fruitfulness of the approach therefore would be better translations and a greater attention to the role of society, unit analysis, and the nature of a category (i.e., unit).

Cross-References

- ▶ Acculturation
- ▶ Activity Theory and Science Learning
- ▶ Cognitive Abilities
- ▶ Culture and Science Learning
- ▶ Didactical Situation
- ▶ Discourse in Science Learning
- ▶ Emotion and the Teaching and Learning of Science
- ▶ Indigenous Students
- ▶ Language and Learning
- ▶ Scaffolding Learning
- ▶ Schooling of Science
- ▶ Team Teaching

Suggested Readings

Leont'ev AN (1978) Activity, consciousness and personality. Prentice Hall, Englewood Cliffs

Roth W-M, Lee YJ (2007) "Vygotsky's neglected legacy": cultural-historical activity theory. Rev Educ Res 77:186–232

Roth W-M, Radford L (2011) A cultural-historical perspective on mathematics teaching and learning: Sense Publishers, Rotterdam

Schraube E, Osterkamp U (eds) (2013) Psychology from the standpoint of the subject: selected writings of Klaus Holzkamp. Palgrave Macmillan, Houndsmills

Vološinov VN (1973) Marxism and the philosophy of language (trans: Mtejka L, Titunik IR). Cambridge, MA: Harvard University Press

Vygotsky LS (1997) The collected work of L. S. Vygotsky (Rieber WR, Wollock J, eds.). Kluwer Academic/Plenum Publishers, New York

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Sociolinguistics

- ► Discourse in Science Learning
- ► Language and Learning Science

Sociology of Science

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Keywords

Anthropology of science; Discourse; History and philosophy of science; Science studies

Sociology of Science and Science Education

Sociology of science offers a number of important contributions to the study of science education. The role of history and philosophy of science is well documented in the development of science curricular materials, but sociology has had a more minor influence in this area. Nonetheless, sociology of science offers an important alternative to the normative views of science often found in applications of philosophy of science to science education. Philosophy of science, particularly from the empiricist tradition, has tended to provide a normative account of theory change, with a focus on the rationality and structure of scientific theories. This has contributed significantly to science education by focusing on the importance experimental work and documenting the value of reasons for theories of conceptual change. History of science has similarly been drawn upon to provide case studies relevant to the development of scientific knowledge for the purposes of teaching concepts and theory change. Sociology of science offers a clear alternative by focusing on the social nature of scientific practices and studying such practices in contemporary settings.

Robert Merton (1973) was instrumental in the development of sociology of science as a field of study. He was concerned, in ways similar to philosophers of the time, with understanding how scientific knowledge was uniquely certifiable. His program of study documented the ways that knowledge in science was certified through social processes adhering to four institutional imperatives: universalism, communism, disinterestedness, and organized skepticism. While these norms were criticized in subsequent developments in the sociology of science, the program of research provided models for the empirical study of scientific practice.

A new sociology of science emerged from the philosophy of Wittgenstein's *Philosophical Investigations* (1958) and Kuhn's (1962) *Structure of Scientific Revolutions*. These sociological studies examined epistemological questions from an empirical point of view. Building on Wittgenstein the scholars sought to understand how meanings were embedded in social practices. These programs of study (e.g., strong programme, empirical programme of relativism) shifted away from the views of philosophy and Mertonian sociology concerned with verifiable and certified knowledge to leave questions about the resolution of controversies and conclusions open to empirical investigations (Kelly et al. 1993). Thus, such studies sought to study the *actual* practices of science through detailed, empirical study, prior to knowing whether a given social group's claims would count as science. This empirical stance and openness provided interesting applications for science education.

Science education has long been interested in promoting goals that include the conceptual knowledge of scientific theories along with knowledge of the nature of science. The sociology of science provides new insights into the inner workings of science and offers the potential to expand the repertoire about what counts as scientific practices in educational settings. Since much of the work of sociology of science has included ethnographic studies of sociocultural practices, discourse analysis of interaction, and institutional analysis, these methodological tools have been viewed as models for investigating the nature of science as it is interactionally accomplished in school science as through detailed, empirical analysis of social interaction. Thus, sociology of science provides ways of expanding what counts as science and ways of investigating science in schools, without specifying detailed normative accounts of scientific theories, practices, or natures.

Applications of sociology of science to science education have led to the empirical study of what counts as knowledge in educational settings. This stance directs attention to examining science-in-the-making as students and teachers seek to construct knowledge and propose ways of understanding through interaction. Such studies draw from educational ethnography and discourse analysis to consider how social practices are constructed, appropriated, and communicated through social interaction over time (Kelly and Chen 1999). Implications of these studies include the needs to consider the social practices that establish knowledge in educational settings. By examining the processes involved in knowledge construction, educational programs can build a more robust view of science and provide potential scientists and non-scientist citizens ways of understanding institutional values and social practices of science. Such examination can demystify the processes leading to scientific knowledge and offer a basis for evaluating the epistemic status of scientific conclusions.

Criticisms of sociology of science as a field are similar to those levied against the application of sociology of science in education. Such criticism focuses on the adherence of seemingly non-epistemic reasons appertaining to the development of knowledge claims. This criticism can be countered by recognizing that reason and rationality are themselves the products of social practices, relying on the social and contextual basis for meaning, institutionalization of norms over time, and the acculturation of members into particular ways of knowing for specific epistemic communities. Nevertheless, sociology of science has demonstrated that the sometimes contentious, agonistic nature of scientific debate that may not be most appropriate for learning science, including even the nature of science. Sociology of science and its implications need to be read and understood from an educational point of view, where considerations of social and cognitive development, pedagogy, and ethics are competing interests with notions of authentic scientific practices.

Increasingly sociology of science and its application in science education have become interdisciplinary. For example, studies from the anthropology and rhetoric science of science have informed both sociology of science and science education. Philosophers are increasingly acknowledging and referring to studies of scientific practices in developing epistemological accounts of science. Thus, the emerging of sociology of science with other empirical studies of science has led to the multi- and interdisciplinary field of science studies, where disciplinary boundaries are less certain or relevant. These science studies are relevant to understanding how scientific practices can be introduced, developed, recognized, and acknowledge in science education settings. The development of interests in environmental sciences, socioscientific issues, and argumentation in science education can be informed on the increasingly detailed, specific, and methodologically inventive science studies.

Cross-References

- ▶ Discourse in Science Learning
- ▶ Empiricism
- ▶ Epistemology
- ▶ Science Studies
- ▶ Socio-Cultural Perspectives on Learning Science

References

Kelly GJ, Chen C (1999) The sound of music: constructing science as sociocultural practices through oral and written discourse. J Res Sci Teach 36:883–915

Kelly GJ, Carlsen WS, Cunningham CM (1993) Science education in sociocultural context: perspectives from the sociology of science. Sci Educ 77:207–220

Kuhn TS (1962) The structure of scientific revolutions. University of Chicago Press, Chicago

Merton RK (1973) The sociology of science: theoretical and empirical investigations. Chicago University Press, Chicago

Wittgenstein L (1958) Philosophical investigations (trans: Anscombe GEM), 3rd edn. Macmillan, New York

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Socioscientific Issues

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Keywords

Learning; Pedagogy; Research; Scientific literacy; Teaching

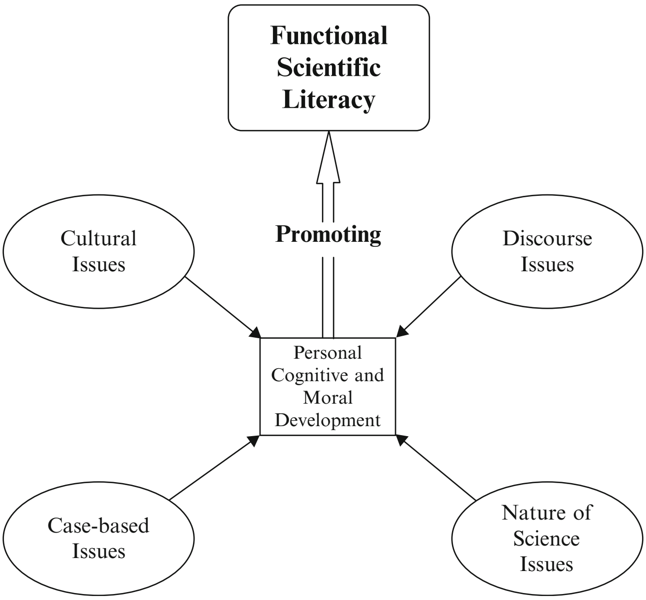
Socioscientific issues (SSI) are a conceptual framework used to guide theory, research, and practice in science education with the ultimate aim of fostering scientific literacy. The framework draws on empirical research and scholarship mainly from psychology (developmental learning theory including moral reasoning and cognitive reasoning, character development), sociology (individual and group identity, community, formation of social norms), philosophy (metaethics, normative ethics, virtue ethics), and critical areas of science education that are conducive to the enactment of SSI in curriculum planning and pedagogy. In short, the SSI movement provides a conceptual framework that unifies multiperspectival epistemological orientations of students and considers the role of emotions and character as key components of science education. Used in their ideal form, SSI contain the following main characteristics:

- Controversial and ill-structured problems that require scientific evidence-based reasoning to inform decisions about such topics.
- Deliberate use of scientific topics with social ramifications that require students to engage in dialogue, discussion, debate, and argumentation.
- Tend to have implicit and explicit ethical components and require some degree of moral reasoning.
- Formation of virtue/character as a long-range pedagogical goal is often associated with SSI.

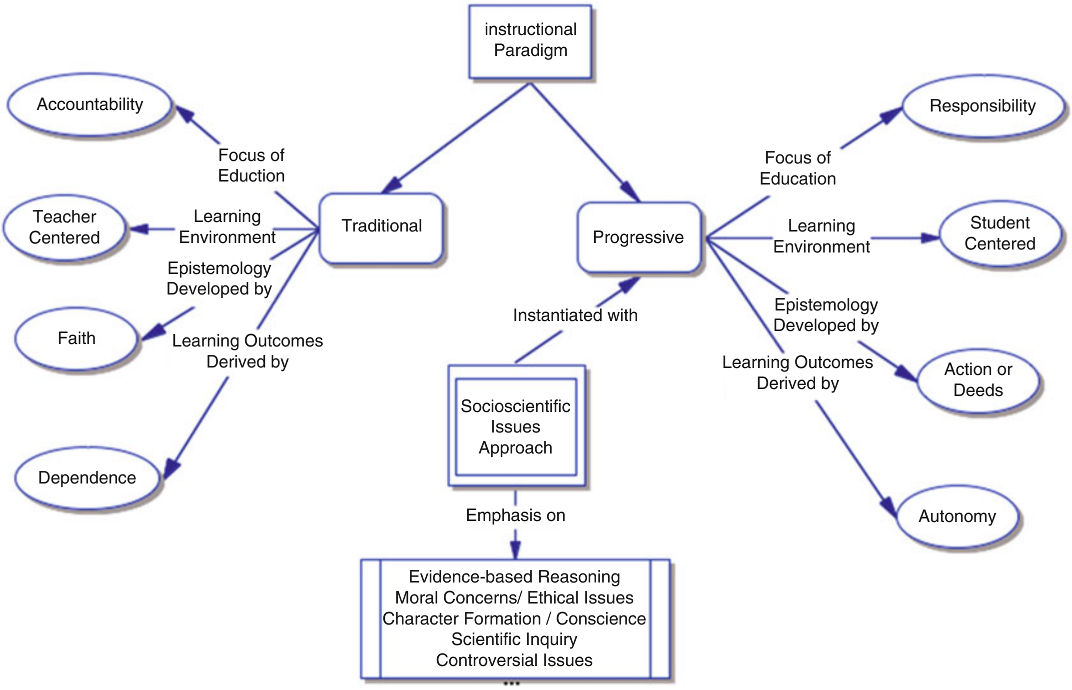
The overarching pedagogical goal is to engage students in the activity of science through exploration, inquiry, questioning, and discourse as they explore issues that are personally relevant to them, as well as relevant to societal and global world views. Deeper conceptual understanding of subject matter becomes necessary to more justly come to resolution of these topics.

Figure 1 depicts a simplified view of key areas of science education, prevalent in the research literature, that are typically tapped to provide a network of understanding while engaging in SSI curriculum development and pedagogy (Zeidler et al. 2005). These areas represent research programs in and of themselves, but can be tapped to help initiate SSI pedagogy. Likewise, there is a reciprocal relationship whereby SSI may help to foster developmental growth in these areas as well. At the center is the nurturing of constructs related to epistemological beliefs that subsume character, morality, rational evidence-based reasoning, emotive reasoning, empathy, caring, and the like – that all contribute to a "functional sense" of scientific literacy. The emphasis on "functional" is important in that it distinguishes between those individuals that may be technocratically competent and those that are ethically astute in the application of judgments that require technical competence – the latter comprising functional intellect and moral inclinations.

SSI are aligned with a progressive view of scientific literacy. Figure 2 contrasts traditional and progressive instructional paradigms and their associated outcomes. Of course, the figure shows extreme endpoints of a teaching continuum and



Socioscientific Issues, Fig. 1 Socioscientific issues framework



Socioscientific Issues, Fig. 2 Pedagogical continuum of learning traditions and outcomes

actual classroom practices may entail movement along different dimensions of the extremes. However, in its purest form, SSI pedagogy stands in contrast to traditional teaching practices and encourages students to prioritize multifaceted factors including interpreting issues, decision-making, solving problems, and engaging in argumentation(Zeidler and Sadler 2008). Certainly, the focus tends to be more on the students rather than the teacher. Attention to these factors is also consistent with ideas that define the “Vision II” orientation to science education found in recent literature.

The term “socioscientific issues” is sometimes written using a hyphen (i.e., socio-scientific issues). While this may be done to appeal to a sense of grammatical style, the use of the terms sans hyphen can also be understood to be quite deliberate. For some, the unassuming hyphen cleaves the social context that such issues entail apart from the science that undergirds them. While it may be suggested that this is an overly academic point, some view the distinction as fundamentally important. The argument is one that views the bifurcation of science into nonnormative components (e.g., data gathering, observation, predictions, scientific methods and processes) and normative components (e.g., prescribing courses of action, choosing to create selected products, decisions about what *ought* to be done) as one that is fraught with peril. While such a distinction is, arguably, conceptually important, it can create a splintered view that allows for the abdication of any sense of responsibility during the practice of science. Some science educators simply do not wish to inadvertently drive a wedge between science proper and the social context in which it resides. That separation is an artificial divorce.

Certainly, SSI can be used as a means to provide a context for argumentation about efficacy of scientific evidence without attention to moral reasoning. Likewise, SSI can be used as a context to develop argumentation skills without attention to the formation of character. Or perhaps SSI may be used as a context to develop more robust understanding of NOS but pay no attention toward an epistemology of human flourishing. This is one reason to choose to use the word “socioscientific issues” rather than the hyphenated version of the term.

The contextualization of scientific content into the problems, experiences, and interests of students’ lives is of paramount importance in SSI pedagogy as well as curriculum development. For example, SSI can be used as a forum for the teacher to challenge students’ core beliefs about subject matter and conceptual understanding of that discipline. The findings from research suggest that differences in content knowledge are related to variation in the quality of informal reasoning (Sadler and Zeidler 2004). More specifically, students that possess more advanced understandings of scientific knowledge relevant to the issue under scrutiny have greater quality or reasoning on SSI and generally commit fewer instances of fallacious reasoning flaws.

Likewise, SSI can be used as a forum for a teacher to challenge students’ normative beliefs related to ethical issues surrounding a given topic. Students are expected to provide justifications for their beliefs related to stances on various topics and challenged to make reasoned judgments about scientific data. Students can also serve as their own facilitators as they discuss, debate, argue, and evoke related forms of discourse to collectively render judgments on vexing normative problems associated with particular issues. These features reflect the kind of sociomoral discourse that is a significant part of the SSI classroom. When students are compelled to consider counterpositions and evaluate evidence or claims from varied sources that may be at odds with one another or dissimilar with their own beliefs, cognitive and moral dissonance is generally created. Dissonance can further be assured when conflicting social norms must be prioritized (e.g., life, affiliation, law, morality and conscience, contract duties, obligation, upholding virtue, social contract, equity, relationships, etc.) thereby creating stronger moral tensions. Dissonance of this nature compels students to negotiate and resolve conflicts and enhances the quality of their own arguments or stances. Using argumentation provides a valuable means to challenge students’ critical thinking and reasoning processes, and it mirrors the discourse practices used in real life in the advancement of scientific and intellectual knowledge. Alternative strategies to argumentation and debate include guided discussions led by the teacher and other forms of group inquiry to investigate common claims made in the media or reside in peer groups.

One of the more long-term and “deeper” goals of SSI pedagogy is aimed at the formation of character (Zeidler and Sadler 2008). In contrast to some notions of character education where students are expected to become socialized and compliant to prescribed norms, the development of character under the SSI framework is centered on the formation of conscience. This is accomplished through a process of normation and requires continuous self-reflection and reflexive thinking. It requires the individual to evaluation and scrutinizes their own reasoning and actions and asks how those tasks can be improved. In short, it is akin to seeking the development of conscience and the seeking of virtue in the Aristotelian sense of deeds par excellence. In this sense the development of character requires something more than mere metacognition; it requires the evaluation of actions in terms of their fit with context. This reflects the dual nature of developing conscience. On the one hand, it requires the ability to look forward and anticipate the possible consequences of decisions and consider important factors like long-term consequences, short-term consequences, impact on the physical and social environments, and impact on different stakeholders. On the other hand, it requires the ability to look backward and understand the historical factors that contextualize the boundaries of the issue at hand. This requires the cultivation of a collective social memory and empathy for past historical environmental and social injustices. It is by these processes that the long-range goal of character development is to be realized. Character by way of normation fosters the inclination to want to do what is right and match moral reasoning with moral behavior.

SSI education has been empirically investigated and particular outcomes have been documented in the literature (Zeidler et al. 2009). For example, studies have linked SSI to outcomes that are important both in science education and general education (Zeidler et al. 2011). Examples include outcomes that include (but are not limited to):

- Promoting developmental changes in reflective judgment
- Moving students to more informed views of the nature of science
- Increasing moral sensitivity and empathy
- Increasing conceptual understanding of scientific content
- Increasing students’ ability to transfer concepts and scaffold ideas
- Revealing and reconstructing alternative perceptions of science
- Facilitating moral reasoning
- Improving argumentation skills
- Promoting understanding of eco-justice and environmental awareness
- Engaging students’ interest in the inquiry of science

More recently, SSI research has been focused on cross-cultural comparisons and research has reflected international partnerships (Zeidler et al. 2013). It has been hypothesized by some that more advanced stages of epistemological reasoning allow individuals to apply a kind of socioscientific reasoning (SSR) akin to scientific habits of mind. SSR is a theoretical construct that entails the ability to tap key traits while negotiating SSI (Zeidler and Sadler 2011). These include skepticism, complexity, multiple perspective, and inquiry. Advanced levels of epistemological reasoning are desirable precisely because those stages allow for the integrated exercise of SSR. It should be noted that indirect evidence exists as well as analytic arguments for the importance and connection of SSR to SSI research and practice. This is certainly an area worthy of future exploration.

Assessment of SSI outcomes for research purposes has clearly been reported in the literature. However, large-scale assessment of SSI curriculum outcomes and instruction is challenging. High-stakes testing like PISA or TIMSS may simply be at odds with the highly contextualized nature of SSI instruction. Outcomes such as epistemological or reflective reasoning, civic engagement, character formation, and the like are simply not conducive to large-scale international assessments. However, there are multiple examples of products for evaluation useful for teachers to consider for their own local classrooms. Such products or artifacts might include:

- Written arguments
  - Poster board presentation
  - Position papers
  - Brochures
  - Letter to the editor (business, school officials, congress, senator, etc.)
- Discussion format
  - Small and large group settings
  - Individual participation within group
  - Debate, report to committee/commission/board
  - Use of effective questioning strategies
- Research efforts
  - Performance of investigative/inquiry research/survey
- Alternative media
  - Power point, video, reenactment, PSA, and video blog

There are numerous ways variant forms of rubrics can be used by teachers to assess the quality of students' evidence-based reasoning as well. Because of the unique nature of each science classroom and the characteristics of students' developmental abilities, the following combinations are left up to the individual teacher:

- Validity of evidence
  - Assertions backed by empirical data

Indicator questions: Validity of evidence – Are student assertions backed by empirical data? Was the correct interpretation of data or use of evidence relevant to position or argument?

- Source of evidence
  - Perceived credentials of study or researcher

Indicator questions: Source of evidence – Has the source of evidence been considered and/or weighted? Have the perceived credentials of study or researcher been examined? Where did the source of the data originate?

- Quality of data
  - Contrasting data based on implied or definitive findings

Indicator questions: Quality of data –Is contrasting data based on implied or definitive research? Have sample size, random versus nonrandom samples, age of data, kind of data, or other data-related issues that play a role in the evaluation of evidence been considered?

- Methodological factors
  - Features and design implications of study

Indicator questions: Methodological factors –Have design features and that have methodological implications of the study been considered?

- Scientific content
  - Interpretation of data in regard to science content

Indicator questions: Scientific content – Is the student's interpretation of the data correct? Have appropriate data in relation to the issue under investigation been selected properly? Have interpretation, weight, and meaning been considered?

The wealth of empirical data reported in the international science education literature supports the position that socioscientific issues are and continue to be a worthwhile use of classroom time that results in valuable pedagogical and developmental outcomes.

Cross-References

▶ Bildung
▶ Environmental Education
▶ Science for Citizenship
▶ Science, Technology and Society (STS)
▶ Scientific Language
▶ Scientific Visualizations

References

Sadler TD, Zeidler DL (2004) The significance of content knowledge for informal reasoning regarding socioscientific issues: Applying Genetics knowledge to genetic engineering issues. Sci Educ 89(1):71–93

Zeidler DL, Sadler TD (2008) The role of moral reasoning in argumentation: conscience, character and care. In: Erduran S, Pilar Jimenez-Aleixandre M (eds) Argumentation in science education: perspectives from classroom-based research. Springer, Dordrecht, pp 201–216

Zeidler DL, Sadler DL (2011) An inclusive view of scientific literacy: core issues and future directions of socioscientific reasoning. In: Linder C, Ostman L, Roberts DA, Wickman P, Erickson G, MacKinnon A (eds) Promoting scientific literacy: science education research in transaction. Routledge/Taylor & Francis Group, New York, pp 176–192

Zeidler DL, Applebaum SM, Sadler TD (2011) Enacting a socioscientific issues classroom: transformative transformations. In: Sadler TD (ed) Socio-scientific issues in science classrooms: teaching, learning and research. Springer, Dordrecht, pp 277–306

Zeidler DL, Sadler TD, Simmons ML, Howes EV (2005) Beyond STS: a research-based framework for socioscientific issues education. Sci Educ 89(3):357–377

Zeidler DL, Sadler TD, Applebaum S, Callahan BE (2009) Advancing reflective judgment through socioscientific issues. J Res Sci Teach 46(1):74–101

Zeidler DL, Herman B, Ruzek M, Linder A, & Lin SS (2013) Cross-Cultural Epistemological Orientations to Socioscientific Issues. J Res Sci Teach 50(3):251–283

Static Picture

► Scientific Visualizations

Stop-Motion Animation

► Slowmation

Student Interest in Science

► Interests in Science

Student Peer Assessment

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Keywords

Peer evaluation; Peer feedback; Peer instruction; Peer judgment; Peer marking

Definition

Peer assessment is a process during which students consider the quality of a peer's work or performance, judge the extent to which it reflects targeted goals or criteria, and make suggestions for revision (Topping 2013). Peer assessment is task specific; the assessment is of the quality of the peer's work, not a student's abilities or personal qualities. The peers can be in the same or different grade, of similar or different ability levels, and can be randomly assigned, teacher assigned, or self-chosen.

Although peer assessment can serve both formative and summative functions, it is important to emphasize the richness of information that comes from formative, non-evaluative peer feedback (Topping 2013). While summative peer assessment, also known *as peer marking* or *peer evaluation*, is usually limited to grading or scoring, formative peer assessment contains qualitative information on the strengths and weaknesses of another student's work as well as suggestions about next steps toward targeted goals and objectives. Therefore, while peer assessment can be used summatively, it is more typically applied in a formative fashion (Bryant and Carless 2010).

Theoretical Framework

Theory and research on peer assessment are grounded in scholarship on feedback, formative assessment, and constructivist learning. A constructivist learning environment that encourages trusting relationships and communication among peers allows for diagnoses of understanding and misconceptions, and honest feedback (Topping 2013). Feedback that is substantive, supportive, and timely can promote learning (Hattie and Timperley 2007). In terms of formative assessment, feedback to learners and teachers involves three main processes: (1) determining, clarifying, and understanding the goals, objectives, and expectations for the task; (2) gathering evidence of and interpreting students' current knowledge and skills through relevant performance tasks; and (3) providing feedback that teachers and students can use to move forward (Wiliam 2010). Under the right conditions, learners can provide useful feedback for each other through interactions between the *assessee* (the peer being assessed) and *assessor* (the peer providing the feedback).

Carefully structured peer assessment helps learners seek answers to three questions that coincide with the process of formative assessment described by Hattie and Timperley (2007) and Wiliam (2010):

1. **Where Am I Going? Goal Setting**
   An understanding of the learning goals for a task is a critical aspect of feedback. As such, one of the major components of peer assessment is the articulation of assessment criteria and expectations, whether through the distribution of rubrics, co-creation of criteria, or explanation and discussion of expectations and goals (Topping 2013). Interactions between teacher and learners and between assessors and assessees about the criteria and expectations for the task can enhance understanding of where they are going, ensure similar interpretations of the goals by teachers and peers, and promote a shared sense of commitment to attaining them (Hattie and Timperley 2007).
2. **How Am I Going? Progress Monitoring**
   Another important element of assessment is information on the learner's progress toward the targeted goals. Such information can include feedback on the performance relative to the goals and expectations or as compared to prior performance. The use of a structured process of critique is helpful for ensuring constructive peer feedback.
3. **Where to Next? Moving Forward**
   The influence of feedback on learning is based on the learner's decisions about where to go next or what to do to deepen learning and improve performance (Hattie and Timperley 2007). Concrete suggestions for improvement and timely opportunities for revision are essential.

Important Scientific Research and Open Questions

Research in different countries has focused on the academic and social benefits of peer assessment; teacher, parent, and student perceptions of its value; and validity and reliability. Much of the available research has focused on writing and has been done in higher education contexts, although children as young as 9 years of age have been successfully involved in the process of peer assessment (Topping 2013).

Research suggests that there is a positive relationship between achievement and peer assessment, particularly in noncompetitive cultures and when learners are trained in constructive feedback techniques. For example, students who engaged in peer assessment that emphasized strengths, weaknesses, and suggestions for improvement of their writing tended to produce higher-quality final drafts than those who received only teacher feedback (Topping 2009, 2013).

Research has also revealed a relationship between peer assessment and social skills. When teachers create a classroom community where learning targets are clearly defined for students and constructive peer critiques are implemented for the purpose of revision, the frequency and quality of help seeking, help giving, and students' attitudes about asking for help have improved (Topping 2009).

Peer assessment can be beneficial to the assessor as well as to the assessee. Observing and critiquing a peer's work places sophisticated cognitive demands on assessors, including monitoring, detecting, diagnosing, and correcting performance and listening, explaining, questioning, and summarizing a concept. Taken together, these high-level cognitive processes can promote the internalization of knowledge and self-assessment by the assessor (Topping 2013).

Studies of the perceived value of peer assessment indicated individual and cultural differences. For example, teachers and parents of children in primary grades seem to value peer assessment more than the students do. Both primary and secondary school students without training or experience had concerns about this assessment practice, but in a study of students in secondary school, learners acknowledged the ways in which assessment of their peers naturally promoted thinking and reflection on their own progress and performance (Topping 2013).

Learners tended to devalue peer assessment in high-stakes educational contexts, competitive classrooms, and when assessment was used for purely summative purposes (Bryant and Carless 2010; Topping 2013).

Research on the reliability and validity of peer assessment or peer marking has examined the degree to which learners' assessment of their peers' work is consistent with their teachers'. The results have been mixed. In instances when peer assessment was found to be inconsistent with teachers' assessment, the quality of training in peer assessment and students' level of involvement in the process were questionable (Topping 2013). In contrast, when learners were taught the appropriate processes, there tended to be surprisingly little difference between peer assessors' and teachers' evaluations. The more elaborated the feedback, however, the more variance there was between the responses of different assessors. In short, when students are trained in the assessment process, reliability is generally at least adequate (Topping 2009).

Although a significant amount of research has shown peer assessment to be a promising instructional tool, more work is needed to understand its implementation and outcomes and to address a concern about the generalizability of the technique across age, culture, and subject areas. Optimal peer feedback procedures should be determined for a variety of contexts in order to ensure high-quality implementation (Topping 2013). Research on peer assessment should expand to more comprehensively examine the elementary and middle school grades as well as language learners and students with disabilities. The role of peer assessment in contexts that stress high-stakes testing should also be examined. Finally, claims that the peer feedback process enhances the self-esteem and social connectedness of children who are socially rejected or disliked (Topping 2013) should be empirically tested.

Cross-References

- ▶ Formative Assessment
- ▶ Student Self-Assessment

References

Bryant DA, Carless DR (2010) Peer assessment in a test-dominated setting: empowering, boring or facilitating examination preparation? Educ Res Policy Prac 9:3–15

Hattie J, Timperley H (2007) The power of feedback. Rev Educ Res 77:81–112

Topping KJ (2009) Peer assessment. Theory Pract 48:20–27

Topping KJ (2013) Peers as a source of formative and summative assessment. In: McMillan JH (ed) Handbook of research on classroom assessment. Sage, Los Angeles, pp 395–412

Wiliam D (2010) An integrative summary of the research literature and implications for a new theory of formative assessment. In: Andrade HL, Cizek GJ (eds) Handbook of formative assessment. Routledge, New York, pp 18–40

Student Self-Assessment

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Keywords

Self-evaluation

Definition

Many terms have been used synonymously with self-assessment, including self-evaluation, self-reflection, self-monitoring, self-rating, self-scoring, self-marking, and self-grading (Andrade and Valtcheva 2009; Brown and Harris 2013; Falchikov and Boud 1989). Broadly, self-assessment refers to an evaluative process during which students assess and provide feedback on their own work. Falchikov and Boud (1989) suggest that self-assessment can serve both formative and summative purposes. From a formative perspective, self-assessment contributes to the learning process by focusing students' attention on areas in need of improvement: Students use their assessments to determine the extent to which they have met designated task criteria or standards and to identify areas of improvement. Serving a summative purpose, teachers can use student self-assessments for grading. Regardless of the purpose of self-assessment, Falchikov and Boud (1989) contend that self-assessment (a) is criterion referenced, meaning that the act of assessment must involve explicitly stated criteria, standards, or expectations, and (b) involves comparisons of one's own work to that set of criteria, standards, or expectations.

Broader and narrower definitions of self-assessment have also been proposed. Taking an expansive stance, Brown and Harris (2013) argue that the act of self-assessment should not be restricted to evaluating work against "socially agreed criteria" (p. 368) because doing so limits the ability to investigate and distinguish between the effects of different types of self-assessment. This broad conception of self-assessment involves students making formative or summative judgments about the characteristics of their work or capability to do work. The judgments may be quantity estimates, such as grading, or quality estimates, such as comparing aspects of one's work to a set of criteria.

Andrade (2010), however, proposes a narrower definition of student self-assessment as a formative, task-specific process during which students first generate feedback on the quality of their work by assessing the extent to which it meets explicitly stated criteria and expectations and then, through a process of revision, use their self-generated feedback to improve the quality of their work and deepen their learning. Andrade emphasizes the formative nature of self-assessment, indicating that self-assessment is done on works in progress in order to inform revision and improvement. According to this definition, a distinction is made between self-assessment and self-evaluation, the latter being a summative process whereby students assign themselves a grade. Andrade warns that summative self-assessment might not promote learning to the same degree as formative self-assessment methods because in summative self-assessment the students' intentions are to produce a desirable yet defensible score rather than to generate useful feedback for revision (Andrade and Valtcheva 2009). Andrade also made a distinction between self-assessment and self-reflection, suggesting that self-reflection is not task-specific, as it calls for students to make judgments about strong or weak abilities for the purpose of engaging in self-discovery and awareness.

Theoretical Background

The major theoretical premise of self-assessment is that it mentally engages students in a process that serves to develop academic self-regulation (Andrade and Valtcheva 2009; Brown and Harris 2013). Students with high self-regulatory skills take ownership over their learning and rely less on teachers to achieve challenging learning goals. The process of evaluating their own work can help students develop skills in regulating their performance and learning, which can lead to deeper, more meaningful learning and ultimately result in higher gains in achievement. Andrade and Valtcheva argue that self-assessment is an important component of self-regulation, indicating that self-assessment makes students aware of the goals of a particular task and prompts them to monitor their own learning by checking their progress in relation to those goals. Similarly, Brown and Harris suggest that engaging in self-evaluative tasks promotes the development of metacognitive competences essential to self-regulation, such as self-observation, self-judgment, self-reaction, task-analysis, self-motivation, and self-control.

Self-assessment can serve self-regulatory purposes by having students describe and generate feedback on their own work. Hattie and Timperley (2007) developed a three-step feedback model: First, focus the feedback on specific learning targets; then, have students consider where their work is in relation to those learning targets; finally, have students articulate what they can do to fill any gaps. To generate feedback using this model, students simply ask themselves: "Where am I going?" "Where am I now?" and "How can

I close that gap?" Meta-analyses of feedback suggest that the quality of feedback can have a large effect on achievement, with an average effect size of 0.79 (Hattie and Timperley 2007). Hattie and Timperley suggest that effective forms of feedback contain information on how to improve performance on a specific task. Students generate this type of feedback when engaging in formative, criteria-referenced self-assessment. Formative self-assessment using rubrics, checklists, and journals has been associated with increased sophistication in the quality of students' writing, as well as increased mathematical vocabulary, better performance on word problems, and higher independence in mathematics problem solving.

Several methods of self-assessment have been devised to assist students in generating feedback on their learning. Brown and Harris (2013) state that methods of self-assessment generally ask students to evaluate either quantity or quality aspects of their work. Evaluating quantity aspects of one's work can include using a scoring guide containing correctly scored answers to assign a grade, score, or rank order or to estimate performance on a test or task. Evaluating quality aspects can include using a rubric to compare the quality of one's work or performance against a set of criteria.

In formative self-assessment, rubrics are often used to judge the quality of performance-based tasks such as writing, portfolios, and presentations. A rubric is a "document that lists criteria and describes varying levels of quality, from excellent to poor, for a specific assignment" (Andrade and Valtcheva 2009, p. 13). Rubrics not only support students in evaluating their own work but also serve as a teaching tool: Rubrics set the target for a task, describe both strong and weak work, and warn against the types of mistakes students tend to make on the task being evaluated. Once students have self-assessed their work using a rubric, they can revise it and use the rubric to repeat the process, at least until self-assessment is internalized. In addition to rubrics, Andrade (2010) suggested that checklists, journals, and student interviews can also be used to engage students in formative self-assessment.

Several important conditions should exist in order for students to receive the full learning benefits of self-assessment. Based on Brown and Harris' (2013) broad perspective, the form that self-assessment assumes, whether it is formative or summative, is irrelevant; effective self-assessment involves high mental engagement, is focused on the processes of self-regulation, and is scaffolded by the teacher. According to this view, good self-assessment is guided by the teacher and asks students to compare their performance against objective criteria, such as correct vs. incorrect test answers, or rubric-based criteria. Andrade and Valtcheva (2009) agree that teachers should play an active role in the self-assessment process, suggesting that teachers provide direct instruction on how to engage in self-assessment, give feedback to students on their self-assessment, and teach students how to use self-assessment to improve their work. Andrade (2010) argues that the climate of the classroom is also important to the success of self-assessment: Students need to perceive and understand the value of constructively critiquing their work and trust that their self-assessments will be respected by their teacher.

Andrade (Andrade 2010; Andrade and Valtcheva 2009) indicates several additional conditions for a formative, criteria-referenced approach, including the incorporation of a revision process during which students use their self-assessment feedback to improve the quality of their work or performance. Another characteristic of formative self-assessment is that students' judgments must not involve assigning a grade or score but should instead focus on identifying ways to revise and improve the work to meet the target criteria.

Important Scientific Research and Open Questions

Studies indicate that self-assessment is associated with learning and achievement. In a meta-analysis of 84 empirical studies of both formative and summative forms of self-assessment, Brown and Harris (2013) found a median effect size of between 0.40 and 0.45. This suggests that, on average, students who self-assess their work achieve almost a half standard deviation higher than those students who do not engage in self-assessment. The meta-analysis also suggests that self-assessment is related to gains in learning and achievement when students are (a) trained in self-assessment strategies; (b) provided guidance in self-assessment through models, correct answers, or teacher feedback; and/or (c) involved in the construction of task criteria and expectations. In addition, self-assessment that involved students in monitoring, rewarding, and making predictions about their achievement and accuracy as compared to objective criteria was correlated with gains in achievement.

Research investigating the accuracy of self-assessment has focused on the degree to which student self-assessments agree with teacher assessments. Young students tend to overestimate their performance by rating their work higher than the teacher, whereas older students tend to underestimate their performance and have ratings that correlate more strongly to teacher ratings (Brown and Harris 2013). The self-assessments of high-achieving, proficient students tend to agree more with teacher assessments than do those of low-achieving students. The research suggests that students' self-assessments agree more strongly with teacher assessments when students are taught to self-assess, have task-specific knowledge of the content, and know that their assessments will be compared to peer or teacher assessments. The tendency of students to inflate their self-assessments when they are counted towards a grade serves as a justification for the use of formative approaches to self-assessment (Andrade and Valtcheva 2009; Brown and Harris 2013).

Many questions about self-assessment are worthy of investigation. Although there is some evidence that self-assessment is linked to increases in motivation and self-regulation, the results from studies of this link are inconsistent (Brown and Harris 2013). Therefore, questions remain about the extent to which self-assessment contributes to motivation and the development of skills in self-regulation. Similarly, claims have been made about the effects of self-assessment on metacognition, yet very little research has investigated these effects. Research is needed to determine whether and how ongoing self-assessment experiences result in more and better metacognitive processing.

Little research has explored the relationship between the accuracy of students' self-assessment and gains in achievement. As noted by Brown and Harris (2013) and Andrade (2010), low-achieving students are often inaccurate in their self-assessments, yet they can still make gains in achievement through self-assessment. This raises the question of whether or not self-assessment accuracy matters. If accuracy of self-assessment is found to affect achievement, research should explore the components of the self-assessment process that contribute to improved accuracy in self-assessment.

Cross-References

- ▶ Formative Assessment
- ▶ Metacognition and Science Learning

References

Andrade HL (2010) Students as the definitive source of formative assessment: academic self-assessment and the self-regulation of learning. In: Andrade HL, Cizek GJ (eds) Handbook of formative assessment. Routledge, New York, pp 106–124

Andrade H, Valtcheva A (2009) Promoting learning and achievement through self-assessment. Theory Pract 48:12–19

Brown GTL, Harris LR (2013) Student self-assessment. In: McMillan JH (ed) Sage handbook of research on classroom assessment. Sage, CA, pp 367–393

Falchikov N, Boud D (1989) Student self-assessment in higher education: a meta-analysis. Rev Educ Res 59(4):395–430

Hattie J, Timperley J (2007) The power of feedback. Rev Educ Res 77:81–112

Student Teacher as Researcher

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The idea of student teacher as researcher should sit comfortably with the intentions of teacher education and the process of learning to teach. It seems obvious that if student teachers are placed in positions where they can learn to challenge their existing views of practice through researching their own experiences of teaching, then such learning should be both valuable and meaningful in shaping their subsequent practice. Despite the apparent common sense of such a view, there is very little literature to suggest it is the case.

Project START (Student Teachers as Researching Teachers, Cochran-Smith 1991) is one of the few examples of the type of approach briefly noted above. Cochran-Smith described project START as being based on the notion of "collaborative resonance" because it was designed to "Prepare student teachers who know how to learn from teaching by inquiring collaboratively into their own practices and who help build cultures of teaching that support ongoing professional growth and reform" (p. 106).

Obviously, for a student teacher to learn about teaching through a student teacher as researcher stance, then such learning about teaching must be embedded in their experiences of teacher education. Project START did just that through a curriculum structured around opportunities for participants to engage in four kinds of teacher research – oral inquiry processes, essays, journals, and classroom studies – all of which were designed to raise questions and encourage data collection and analysis of particular aspects of learning about teaching. In many ways, project START focused on what Munby and Russell (1994) described as the "authority of experience."

Munby and Russell's research in the authority of experience in learning to teach led to two major student teacher as researcher outcomes as documented by Derek Featherstone (see Featherstone, Munby and Russell, 1997) and Shawn Bullock (see Russell and Bullock, 1999). Both of their accounts of researching their practice illustrated how, through creating situations that encouraged them to recognize and build on the authority of their own experience, their learning about teaching was substantially enhanced.

Featherstone's research clearly illustrated how his views of teaching and learning changed as a consequence of seeking feedback from his students about their learning in his classes. As a consequence of his careful "listening to his students," he found new ways to better construct his teaching in line with his hopes for his students' learning and their feedback on the quality of that learning. One particular aspect of his research was on the teaching of "natural succession" through which the data he collected and the subsequent analysis he conducted highlighted the value of purposeful inquiry into teaching by listening to, and learning from, his students. Featherstone's study showed how a student teacher as researcher stance fundamentally influenced his learning about teaching in very powerful and explicit ways.

Bullock, another student teacher who responded to the authority of his experience, launched into an extended research project in which he spent a considerable period of time documenting and analyzing his practice. As a consequence, he began to see differences between his views of science learning and the actual science teaching he was employing in the classroom. He therefore decided to step out and take risks in his practice and encourage the learning he hoped for rather than be secure in the teaching approach that gave comfort through traditional curriculum delivery. Although as a novice teacher he felt uncomfortable in not directing his students' learning of science in ways he was more familiar with, he soon saw the value in allowing his students to explore science for themselves. His experiences of learning to teach science through researching his practice created insights into teaching that fundamentally shaped his practice. Bullock's student teacher as researcher stance set an approach to learning about teaching that dramatically impacted his future career as he became a thoughtful teacher researcher and later teacher educator (Bullock 2011). In both cases, his grounding in researching his own practice as a student teacher gave him the impetus to do the same in his ongoing career.

In a longitudinal study over 3 years, Loughran (2004) documented his student teachers' research into their own practice. Again, the substantive approach was embedded in their own experiences through which they accepted greater responsibility for directing their own learning about teaching. Loughran encouraged the use of anecdotes as a catalyst for his students to study their practice. That approach served as a way of helping them to recognize the differences between what they were doing and what their students were learning and how they interpreted the gap between purpose and practice. Anecdotes encouraged his student teachers to draw on critical incidents in order to meaningfully reflect on their practice and pursue deeper understandings of the problematic nature of teaching.

His student teachers' projects consistently illustrated how they chose to revisit their own experiences and to begin to reconsider concrete aspects of their teaching that they could do something about. In so doing, they began to see new ways of investigating and interrogating their own learning about teaching and to build knowledge of practice that was informing and useful to them. Many of his student teachers' research studies were not pre-organized as a form of assessment per se, but rather developed as a response to emerging issues in their practice.

For those teacher educators invested in student teacher as researcher, a major hope is that novice teachers come to better understand the value of research in teaching and learning and to highlight how informative and applicable it can be to their classroom practice. Bullock's work is certainly a strong and important example of the value of setting such a foundation to learning to teach and illustrates well how important studying practice is to teachers as a way of improving the learning outcomes for their students.

Cross-References

- ▶ Self-Study of Teacher Education Practices (S-STEP)
- ▶ Teacher Professional Development
- ▶ Teacher Research

References

Bullock SM (2011) Inside teacher education: challenging prior views of teaching and learning. Sense Publishers, Rotterdam

Cochran-Smith M (1991) Reinventing student teaching. J Teach Educ 42(2):104–118

Featherstone D, Munby H, Russell T (1997) Finding a voice while learning to teach. Falmer Press, London

Loughran JJ (2004) Student teacher as researcher: accepting greater responsibility for learning about teaching. Aust J Educ 48(2):212–220

Munby H, Russell T (1994) The authority of experience in learning to teach: messages from a physics method class. J Teach Educ 4(2):86–95

Russell T, Bullock S (1999) Discovering our professional knowledge as teachers: critical dialogues about learning from experience. In: Loughran J (ed) Researching teaching: methodologies and practices for understanding pedagogy. Falmer Press, London, pp 132–151

Student Teachers' Needs and Concerns

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Student teachers enter the university training program to become a teacher first of all on the basis of having been a student in school for many years. Their a priori concepts about being a teacher and their beliefs about teaching and learning are mainly based on their experiences collected while having been high school students and by being a learner at university. Because many teaching practices in high schools all over the world, and also in universities, especially in chemistry and physics education, are not necessarily in line with educational theory, e.g., in terms of a student-centeredness and a constructivist approach to teaching and learning, the student teachers' a priori beliefs often tend to be very much teacher-centered, behavioristic, and mainly focused on rote subject matter learning (Markic and Eilks 2012). These beliefs mostly exist in the student teachers' subconscious and can act as filters through which new information about becoming a teacher is influenced and thus can act as hindering factors in student teacher learning. Unfortunately, learning within many teacher training programs follows similar pedagogies and therefore tends to reinforce these beliefs. Considering the impact of beliefs about teaching and learning in general and in science education in particular, there is a need to make student teachers' prior beliefs explicit and to confront them with modern educational theory, e.g., from the field of constructivist learning and student activating pedagogies. Making these beliefs and initial concepts explicit and confronting them with modern educational theory and vignettes from the classroom can be a first point for initiating conceptual change (Markic and Eilks 2012). This process of explication can help student teachers become more aware of the importance of unconscious beliefs and concepts about teaching and learning.

Recognizing the Nature of Concerns

Based on a constructivist approach to teacher learning, research has revealed that student teachers are able to substantially change their beliefs from traditional to modern beliefs. A core issue for this change is to allow student teachers to be confronted by, and thoroughly reflect upon, modern teaching and learning practices – beyond the practices of the university – as soon as possible. In so doing, student teachers have been shown to develop and change their perspectives on teaching and learning (Hoy and Woolfolk 1990). However, when entering school for teaching internships or after finishing teacher education, prospective teachers are confronted by many concerns.

Student teachers most frequent concerns seem to be related to their own subject matter adequacy and their potential inability to answer pupil's subject-related questions. But also questions of discipline, pupils' reactions to them, or the evaluation of their lesson plans and expectations of their supervising teachers are also areas of major concern. In the case of internships or being a trainee teacher, the student teachers also have concerns about other aspects of adequacy and personal evaluation, e.g., about the frequency of visits and observations by supervisors and about being graded themselves as well as their grading of their pupils. That means before entering schools their main concerns are in the area of subject matter knowledge, general educational skills, and formal aspects of the teacher education program. Before entering school there is much less concern about those topics which are typically the main part in domain-specific educational courses in teacher education, like knowledge about instructional design, methods of presenting subject matter, or assessment of pupils' learning (Fuller 1969).

It has been shown that in the first weeks of teaching, student teachers are mostly concerned about themselves, whether they have sufficient subject matter knowledge or being able to keep discipline in class. A poorly developed background in subject matter knowledge leads to many concerns and a lack of self-confidence to teach science and to react appropriately to pupils' questions (Appleton 1995). Lack of routines about working with the pupils also hinders teachers' organization of domain-specific learning processes. That means, in teacher training, there is first of all a strong need to develop good and broad subject matter knowledge in the domain of later teaching as well as developing standard routines to manage classroom organization. Other than with the subject matter knowledge and the question of discipline, student teachers' concerns about specific issues of teaching and learning science also play a role and may appear amorphous and vague.

Teaching Experience

After experiencing teaching science during their first teaching experience, many naive concerns become more concrete and real. While student teachers prior to teaching are mainly concerned about their subject matter expertise or skills in classroom organization, following their initial experiences in teaching, concerns shift towards the learning of their pupils and their influence on it. Concerns change from the areas of subject matter knowledge or general educational knowledge towards concerns about the student teachers' pedagogical content knowledge.

A student teacher who is not familiar with the subject matter will have difficulties developing pedagogical content knowledge, e.g., how to deal with student alternative conceptions or how to select suitable models for explanation. Sufficient subject matter knowledge is a necessary prerequisite for the teacher to ask appropriate questions, suggest suitable investigations, or to assess student learning. However, this knowledge about, e.g., appropriate tasks, pedagogies, or students' alternative conceptions is not a part of the subject matter knowledge alone but needs additional well-developed pedagogical content knowledge.

Within the domain of pedagogical content knowledge, student teachers first of all need to develop their knowledge about pupils and their learning. This knowledge can also be of use in modifying and reconstructing student teachers' images of themselves as a teacher and about their own learning in teacher education. This self-reflected activity accompanied by a growing body of knowledge can help them to develop procedural routines to integrate classroom management and domain-specific instruction. Often, preservice programs fail to address these tasks adequately (Kagan 1992) and so these concerns persist until the student teacher learns how to confront and address them at a personal level.

Cross-References

- ▶ In-Service Teacher Education
- ▶ Primary/Elementary Science Teacher Education
- ▶ Secondary Science Teacher Education

References

Appleton K (1995) Student teachers' confidence to teach science: is more science knowledge necessary to improve self-confidence? Int J Sci Educ 17:357–369

Fuller FF (1969) Concerns of teachers: a development conceptualization. Am Educ Res J 6(2):207–226

Hoy WK, Woolfolk AE (1990) Socialization of student teachers. Am Educ Res J 27(2):279–300

Kagan DM (1992) Professional growth among preservice and beginning teachers. Rev Educ Res 62(2):129–169

Markic S, Eilks I (2012) Using a mixed methods design for characterising freshman science student teachers' beliefs about science teaching and learning – a comparison of student teachers' beliefs from four different science teaching domains. Int J Sci Educ 22(3):185–201

Subject Matter Knowledge for Teaching

▶ Pedagogical Content Knowledge in Teacher Education

Summative Assessment

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Keywords

Accountability; Assessment; External assessment; Large-scale assessment; Monitoring; Summative assessment

Summative assessment refers to assessments which seek to obtain comprehensive information about student competence in a domain (e.g., science) for an evaluation of student learning. Teachers use summative assessment at the end of a unit or school year to gather evidence about students' mastery of the content covered throughout the unit or school year as a basis for grading. These classroom-based summative assessments are closely related with the learning aims of the instructional unit and thus the curriculum. However, summative assessments are also used by other agents within the education system, such as policy makers. Policy makers, for example, use summative assessments for monitoring the efficiency of parts of the educational system (e.g., specific curricula) or the education system as a whole (e.g., in comparison to other countries' education systems). These external large-scale summative assessments are not directly aligned with curriculum. However, in order to serve their purpose to measure students' mastery of the learning goals laid out in policy documents at a particular stage in the education system, they should be related to a model of students' progression in mastering the learning goals. Summative assessments need to build on a model of student mastery of the domain. In the simplest case, such a model embraces two levels, non-mastery and mastery. Typically students are considered to have mastered the domain or a particular aspect of the domain (i.e., one learning goal) when they achieve a minimum score on a set of tasks representing the domain or the particular aspect of the domain. At best, summative assessments are building on a model embracing a hierarchy of levels indicating different levels of mastery each represented by a specific set of tasks. In case of external large-scale assessments, these tasks are typically multiple-choice or short-answer questions. In case of classroom-based summative assessments, these tasks may include multiple-choice items but are also often based on more complex open-ended items.

Cross-References

▶ Assessment: An Overview
▶ Assessment to Inform Science Education
▶ Coherence
▶ Formative Assessment
▶ Large-Scale Assessment

Sustainability and Science Education

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We live in the "Anthropocene" era, an era in which human activity plays a significant role in shaping conditions on our planet. In order to survive as a species on Earth, we need to monitor, understand, forecast, mitigate, and adapt with the changing social, economic, biological, geological, and physical conditions on Earth. Successfully addressing these vital challenges requires a continuously iterative process of learning, building, integrating, and using knowledge, including that of natural and social science and humanities throughout society. This recognition presents new challenges that necessitate restructuring the purpose, content, and approach of education. The focus in this entry is on changes needed in science education for this to contribute to a sustainable future for all.

The United Nations Decade of Education for Sustainable Development (2005–2014) aimed to raise awareness internationally of the need for education that supported the multiple goals of sustainable development, as articulated prominently in the 1987 Brundtland Commission document *Our Common Future*. Sustainable development is defined by the Brundtland Commission as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The term "development" is hotly debated in this context, with questions as to whether it should refer to human well-being, rather than only to the use of diminishing physical resources and the raising of Gross Domestic Product figures. The meaning of sustainability and sustainable development will continue to evolve and be debated. Nonetheless, the broad concept and the fundamental uncertainty of an evolving understanding of a rapidly changing world urgently direct our attention to changing how education can help humanity cope and adapt with the changes.

Important changes in science education – and indeed in all areas of education from preschool through lifelong learning – are needed to continue to prepare students to play a role in advancing knowledge in the sciences and, equally importantly, prepare children and adults to make informed decisions and take individual and collective actions in effecting a transition to a sustainable future for all on the planet.

Science education needs to adapt to fulfill the needs of society in the near and far term. The critical issue is adaptation to a changing paradigm of science, a new one that fully embraces a mix of mono-, multi-, inter-, and transdisciplinary research, that enables social innovation as well as marketing-driven technological innovation, that recognizes and incorporates a diversity of sources and forms of knowledge, that addresses ethics and values in the conduct of and choice of research in science, and that enables and encourages meaningful dialogue with stakeholders in society at large.

What then are the key elements of this new paradigm of science?

In addition to domain-specific knowledge from expertise in narrowly focused "silos" of science that is the core of the reductionist approach, multi-, inter-, and transdisciplinary science and systems thinking that draws more broadly from social and natural sciences and humanities perspectives is essential for addressing the complex challenges of a rapidly changing global system. Complex challenges – ones that involve a system or systems in which the components are coupled nonlinearly with feedback loops and time delays – require a system-level, holistic approach. Simply summing the behavior of the components does not provide an adequate understanding or description of the whole system. Since we as humans are inseparable and significant actors in the complex socio-ecological system of the planet, this makes the need for integrative, multi-, inter-, and transdisciplinary science processes essential.

Models and scenarios built from the output of models are essential tools in understanding complex systems. They facilitate our thinking about complex issues, which are generally characterized by both qualitative and quantitative information from multiple sources and high degrees of uncertainty in the information. Models are fundamental to the way human beings think. They are approximations of the behavior of phenomena and events of the world and reflect perceptions of patterns and efforts to categorize, explain, and predict future behavior of physical, biological, social, and economic phenomena and systems. Models are essential in organizing and interpreting information, whether implicit and intuitive, or elaborate mathematical constructs. Models are becoming increasingly important in social sciences, not only in natural sciences and engineering, where they are well-established tools (Klüver 1998; Lehrer and Schauble 2000). On one end of the scale, models may be greatly simplified associations, elaborated metaphors, or mental representations, or at the other end of the scale, they may be highly elaborated mathematical and computational constructions, such as system dynamics or agent-based models. The results produced from these models do not give "the answer," nor can they. What the results can provide is a set of potential options and new insights to be weighed and considered with due regard to stakeholder values, local conditions, and the fundamental limitation of any model as an approximation to address a specific question and fed by imperfect data.

Transdisciplinary science includes relevant stakeholders – i.e., those who may exert influence on or be influenced by the issues under consideration – in framing the research questions; collecting, analyzing, and interpreting the data; and communicating the knowledge developed through the research. This approach creates important opportunities for mutual learning among the researchers and the community in which the research occurs, thus potentially leading to more informed and effective public and policy decisions and actions. It also allows for discussion and consideration of the multiple values that typically characterize the views of societal actors, including the scientists themselves, regarding any given issue for scientific research.

How can science education develop and improve in the context of the Anthropocene and the new paradigms of science?

The structural and curricular changes in science education needed to respond to this new paradigm of science include the following:

- Improving and expanding problem-focused, project-based learning that draws upon multiple domains of knowledge as needed for the problem at hand

- Developing stronger collaborative and communicative skills
- Building an understanding of the uses and processes of modeling in science
- Incorporating greater consideration of social, ethical, and cultural aspects and implications of science and technology

Greater emphasis on learning to learn and learning critical thinking, rather than relying on mastery of an expansive but shallow knowledge base, is not a new issue and is not tied to sustainability, per se. Nonetheless, improvement in these aspects of learning is sorely needed to support learning that strengthens resilience and adaptability.

A key structural and curricular change needed in science education to respond to this new paradigm of science is change in the desired forms of learning, a change that maps onto the changes in science *per se* – from reductionist and convergent and bounded by the discipline divisions of the past to expansive, collaborative, and transdisciplinary.

These changes can be implemented at every level of education from preschool through tertiary education and in informal and lifelong learning contexts. Developing coherent pathways of learning from early childhood through university and lifelong opportunities should be a high priority in order to give learners at every stage of development a connected and progressively more focused set of thinking skills, knowledge, and insights. Of course, education of teachers and continuing professional development must be a major part of any strategy for any substantive educational change, and that is equally so here. So too, expanding change from an isolated lesson about change to design and daily practice in the operation of the classroom, school, and education system in each community or region is crucial (see, e.g., Stone 2009). New patterns of behavior and operation are far stronger "lessons" when seen and experienced in the daily environment than when presented only in abstract, didactic forms.

There are many examples of successful efforts to implement these approaches in many locations around the world, and a number of resources are available to support the transformation of education at various levels and different conditions and cultures. A few examples follow to indicate the range of efforts, levels, and materials available.

Encouraging students to engage with their community as part of their science education projects – e.g., measuring noise levels or collecting airborne particle samples on a filter in heavy-traffic areas and conducting citizen response to the measurements as surveys – provides experience with multi- and transdisciplinary science. This transdisciplinary research in which students are the stakeholders, as are the teachers and parents and members of a community, not only can change the motivation of students to engage more deeply with the science, but also give them practical experience in applying multidisciplinary knowledge and challenge theoretical knowledge with real experience. In yet another regard, this type of activity lends itself well to constructing and using computational models at age-appropriate levels to interpret the data gathered. This kind of activity has also been at the heart of some after-school programs and summer camps with an environmental focus.

Social choices can also be used to introduce modeling, starting with elementary school-age children. An example that engages children in modeling and empirical testing of their model is to build a simple model to illustrate and predict decision making by one of their cohorts. Ask a class where they think a certain child in another class will sit in the lunchroom tomorrow. Starting with a simple diagram of the space, including the entrance normally used, tables can be assigned with letters and chairs at the table numbered. Children will usually either just quickly guess a location or say they don't know. If they are asked what do you see when you walk in the lunchroom and what might make you choose one seat or another, then the class will start suggesting possible decision factors, such as the location of a supervisory teacher, being near a particular friend, being far from groups of younger or older children, distance from the end of the lunch line, or proximity to the windows. The factors are written on the board or set of cards. Once this process of elaborating factors that influence where someone might sit is completed, the factors can be ranked by priority. Out of this a simple decision tree can be illustrated. Then, the children can test their model by observing the path and choice of the child at lunchtime and later critiquing the model based on the outcome of their observations.

Modeling as a strategy for learning physics at the university and high school level has been strongly advocated (Jackson et al. 2008) and demonstrated and extensively tested in introductory courses using computational modeling (Chabay and Sherwood 2011). Computational agent-based modeling in social sciences has also been implemented at the tertiary and to a lesser degree at secondary levels by Marco Janssen and colleagues at Arizona State University.

Computer and mobile app games already on the market or readily modified versions of commercial games have been used in programs in and out of schools to involve students in a creative and learning processes (see http://www.futurelab.org.uk/sites/default/files/Computer_games_and_learning.pdf). Since game engines actually are forms of computational models, they can be used to provoke discussion and exploration of how models can be used for decision making. In the wide and growing array of computer games now burgeoning on mobile platforms, games built upon models of politics and business have become “fair games,” too.

A number of universities have formed partnerships with schools from preschool through secondary school in their communities and regions to support science education and other areas of learning. These provide incentives to students, particularly for minority and disadvantaged youth to stay in school and form relationships with higher education institutions. This creates an important, though often quite difficult, step in building a more coherent pathway through the educational landscape.

Informal learning environments – e.g., after-school programs, museums and science centers, public science events, and specialized camps – are very important in the landscape of science education (http://www.astc.org/sciencecenters/index.htm). Not only do they provide additional science learning experiences, often with good social, collaborative, multidisciplinary project focus, but they also create links with parents and other adults who become engaged in new experiences of science through their children or as part of adult groups. Science centers and museums are also important potential partners with global change research institutions and programs in that they can function as boundary institutions between local stakeholders and the researchers for mutual learning process.

Cross-References

- ▶ Environmental Education
- ▶ Integrated Science
- ▶ Learning Science in Informal Contexts
- ▶ Science for Citizenship
- ▶ Socioscientific Issues

References

Chabay R, Sherwood BA (2011) Matter and interactions, vol 1, 3rd edn, Modern mechanics. Wiley, New York

Jackson J, Dukerich L, Hestenes D (2008) Modeling instruction: an effective model for science education. Sci Educ 17(1):10–17

Klüver J (1998) Modelling science as an adaptive and self-organising social system: concepts, theories and modelling tools. In: Ahrweiler P, Gilbert N (eds) Computer simulations in science and technology studies. Springer, Berlin

Lehrer R, Schauble L (2000) Modeling in mathematics and science. In: Glaser R (ed) Advances in instructional psychology. Educational design and cognitive science. Lawrence Erlbaum, Mahwah

Stone MK (2009) Smart by nature: schooling for sustainability. Watershed Media, Healdsburg