The version of record is:
Taber, K. S. (2017). Science education as a field of scholarship. In K. S. Taber & B. Akpan (Eds.), Science Education: An International Course Companion (pp. 3-19). Rotterdam: Sense Publishers.

Science education as a field of scholarship

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Science education practice and research

Science education is a key area of activity internationally. Science education is a major field of practice, with science (and individual science disciplines) being taught and learnt at various levels, both formally (for example in schools) and through more informal approaches (such as the learning that takes place when people visit science museums) all around the world. In most countries, science is seen as a key component of schooling, and higher education in science subjects is usually considered of major importance for meeting societal needs such as ensuring the 'supply' of scientists, engineers and other professionals working in scientific fields and for ensuring sustainable economic development.

This major field of practice is supported and explored through the academic study of science education. Science education research (SER) is a well-established, major area of research (Fensham, 2004) that can inform the practice of science education. This present chapter considers the nature of science education itself as a scholarly field: one that is both about, and looks to inform, the practice of science education. The subsequent chapters in this international companion to science education offer introductions to some of the key research areas in science education that can inform practitioners (such as classroom teachers and college lecturers, education officers of scientific societies, outreach officers in university science departments, educators working in museums and science centres, subject officers in examination and curriculum authorities, and so forth) in their work. In many of the chapters authors draw upon research to make specific suggestions for effective teaching practice.

The focus of science education as a field of scholarship

Research is the process of developing new public knowledge - knowledge that helps us understand phenomena better, and - hopefully - informs actions in the world that are more successful in achieving our goals. Science education, as a research field is therefore concerned with developing knowledge about the learning of science, and the teaching of science. This knowledge helps us better understand phenomena such as:

- why some science topics are usually considered more difficult than others…
- …and why some students do not experience the same learning difficulties as their classmates;
- why students often misunderstand some science concepts;
- why some classroom activities undertaken in science lessons are more motivating than others;
- the different ways teachers can organise practical work;
- how science textbooks influence teaching approaches in some countries;
- how teaching models and analogies influence students' developing understanding of science concepts.

Science teachers should not only know about the findings of pedagogical research, but have some insight into the processes by which such knowledge is constructed. This chapter explains how research in science education is similar to, and yet different from, research in science, and outlines some key ideas used to discuss educational research and the common approaches and tools used.

Educational research and SER

Educational research is primarily concerned with the processes of teaching and learning (Pring, 2000), and science education is a subset of educational research where the focus of what is being learnt and/or taught is science curriculum content. That may seem to suggest that science education as a field is little more than the application of more general research in education to science learning contexts. However, that would be too simplistic an assumption. Teaching and learning are very complicated processes, and because they are complex there are many aspects of teaching and learning that we cannot simply treat generically. That is, we cannot simply say that (for example) learning happens 'this' way and teaching is best done 'that' way. As researchers are dealing with complex systems, context is often very important. That context can involve many components.

So it may make an important difference whether the class consists of 6-7 year olds or 13-14 year olds; it may matter when the class is mixed-ability or a 'set' or 'stream' of similar ability students; it might make a difference whether the language of instruction is English, or French, or Japanese or some other language (as different languages offer different resources for communication and learning); and it often makes a substantive difference whether the subject of a class is romantic poetry; the causes of the industrial revolution; trigonometry; redox reactions; reproduction in flowering plants; electromagnetic induction; or the merits of nuclear power supply. It may also make a difference whether the class is taking place in a well designed and well resourced classroom in a peaceful and wealthy society or in a hastily put together shack, with its corrugated iron roof noisily vibrating in the wind, in a poor, war-ravaged country. It makes a difference whether the teacher has minimal qualifications, or has earned a subject specialist degree and post-graduate teaching qualification. The reader can readily see that these examples can be multiplied many times.

Research can inform all such contexts - but application will not be uniform in every context, and research carried out in one place can not always be assumed to tell us much about a very different context. Some principles are generally applicable - but how they can be applied may still vary according to teaching and learning context. What works with a class of 15 high-aspiring, self-assured, fee paying students in a elite selective school may not work with a class of 40 students from an area of poverty where the children are under-fed, and need to fit school around working to help their families. It cannot be assumed that a pedagogy that has been shown to be effective when employed by a highly qualified, highly skilled, experienced teacher who has been trained in the particular techniques will work when implemented by all other teachers. For that matter, an innovative approach may sometimes be more effective when used by an enthusiastic novice teacher committed to the pedagogy than when employed by a much more experienced teacher who already 'knows' it is not going to be successful.

Levels of SER

Curriculum area is then just one aspect of teaching and learning context that can make a difference. Because of this, much general educational research that has been carried out in other subject teaching contexts may be relevant to science teaching. Yet this cannot be assumed to be so: it is often necessary to test how theories, principles and recommendations for practice deriving from other areas of research actually apply in science teaching and learning contexts. It is also the case that the unique features of science as an area of human activity lead to particular pedagogic issues that may not arise in other curriculum areas - so science education has its own specific foci and emphases. An obvious example is that of practical work in science and the science teaching laboratory which is a particular focus that only arises in science teaching. A less obvious example perhaps, but an important one nonetheless, is the extent to which learners who come to science classes often have existing alternative conceptions of science topics which are often inconsistent with the ideas they are expected to learn.

It has been suggested (Taber, 2013) that educational research carried out in science teaching and learning contexts can be considered to fit one of three levels of SER (see Table 1). This typology is of course just a model, and it is not suggested that all studies obviously and unambiguously fit into one of the categories. However, it may be a helpful way of thinking about SER.

Level of SER	**Focus**	**Examples**	**Comment**
Collateral	General educational issue	Does how long a teacher waits after asking a question, before selecting a student to respond, influence the quality of response? Can peer tutoring be used as a means of challenging the most able learners in a class?	These are relevant to science teaching, but findings are likely to apply to other curriculum subjects just as much.
Embedded	Wider educational issue to be understood within the context of science teaching and learning	How can dual-encoding theory (about the cognitive processing of verbal and visual information) support learning about the circulatory system? How can tasks with higher order cognitive demand be incorporated into studying the classification of living things?	These are principles relevant to teaching across the curriculum, but where application needs to be related to the specifics of disciplinary subject matter.
Inherent	Issue arising from the specific of science teaching and learning.	Do students appreciate the affordances of chemical equations in linking between laboratory phenomena and submicroscopic models of matter? What are pupils' moral and aesthetic responses to dissection in school science?	These are questions that only arise in science education, as they relate to something specific about subject content.

Table 1: Research carried out in science learning contexts varies in the extent to which it is specific to science education.

In this scheme some research carried out in science classrooms (labelled collateral SER) is about general educational issues, and the choice of a science teaching and learning context is often little more that a convenience. Imagine a researcher interested in a general educational question who asks teachers at a school to volunteer to take part in a study. Perhaps the science teacher is interested in taking part, and the history teacher is not. In another school it may have been the geography teacher or maths teacher who offered to help. Surveys that are carried out in large numbers of classrooms may include some science classes as part of a more diverse sample. It may be then that there can then be some analysis by subject - but only when the sample size and method used to build the sample allow meaningful comparisons of that type.

Embedded SER

Other research may explore more general educational issues, but in such a way that the location of the research in the science class is a principled choice. So there are many educational theories, principles and ideas which are quite general, but which could be tested in regard to their value in specific (science) teaching and learning contexts. So the notion of 'scaffolding' learning is a general idea about how to support learners in gaining competence in new areas - but the idea needs to be operationalised in particular contexts. We might ask how to effectively scaffold

- learning about the theory of natural selection;
- learning to undertake the calculations needed when using titrations in quantitative chemical analysis;
- learning how to test the principle of conservation of momentum in the school laboratory;

and so forth.

Another example is the general principle that teachers should include tasks requiring higher order cognitive skills (such as synthesis and evaluation) in their lessons. SER might look at what that means when teaching 7 year olds about types of animals, or 13 years olds about the periodic table, or 18 year olds about nuclear reactions, or setting up a museum exhibit about the extinction of the dinosaurs.

There are many such areas of general educational theory that are believed to apply widely in teaching but where more specific research (embedded SER) is needed to see how they might be best applied in particular science teaching contexts. However there are also issues that arise specifically from the teaching and learning of science that would not be directly relevant elsewhere in the curriculum. Thus some studies in science teaching and learning contexts can be considered inherently science education studies (inherent SER).

Inherent SER

For example, there are many common alternative conceptions about science topics that learners bring to science classes. Most people have an intuitive notion of how forces are related to the motion of objects. These ideas are often very similar, and are at odds with the formalism of physics taught in school science and college physics courses. Research suggests that not only do pupils often enter school with these ideas already established, but they very often retain the ideas despite teaching. That presents a very specific (but rather important) science teaching challenge, that is reflected in many science topics in the curriculum. This has motivated a great deal of research about the nature of learners' science ideas (see chapter 'The Nature of Student Conceptions in Science'), how these might change of time, and the kinds of teaching able to bring about desired conceptual change.

Another major issue in science education concerns how to organise science practical work such that it is a 'minds-on' and not just a 'hands-on' activity (see chapter 'Minds-on Practical Work for Effective Science Learning') as often during school laboratory work students are too busy thinking about the organisation and safe manipulation of materials to actually reflect very much on the purpose of the activity and the theoretical significance of their observations. This has become a major focus of concern in science education.

Other examples of foci of inherent SER would be

- how to teach learners about the nature of scientific ideas such as theories, principles and laws - for example, that theories can be well-evidenced, robust, explanatory schemes, and yet should be considered as provisional, theoretical knowledge;
- how to teach students about the affordance of particular representations such as chemical equations, and circuit diagrams, or the kinds of 'tree' diagrams used in cladistics;

- how to best teach evolutionary ideas to students from communities which reject evolution on religious and cultural grounds;
- how can teaching models of energy be developed which offer authentic reflections of the scientific concept, but are not too abstract for lower secondary school students to engage with…

Issues such as these arise from the specifics of teaching and learning science, and so are intrinsic to the professional concerns of science teachers, whilst being of little direct relevance to teachers in other curriculum areas.

Science teacher classroom research

It is the existence of topics motivating inherent SER that supports the existence of a distinct scholarly field of science education. Such a field is both dynamic and permeable. It is dynamic because active topics of interest change over time (Fensham, 2004; Gilbert, 1995), and it is permeable both in terms of ideas and scholars. Ideas from many academic fields become adopted and adapted in SER, and ideas first developed in the field may come to be used more widely. Some people who contribute to SER spend their entire careers doing so. Others may shift into or out of the field to and from cognate areas (such as educational psychology, sociology of education, mathematics education). Some researchers continue to work in the field in parallel with working on projects in other areas. There are also subfields, such as physics education research, chemistry education research, biology education research, astronomy education research, etcetera, within SER, and a wider field of 'STEM educational research' which encompasses issues of interest across teaching subjects such as science, technology, engineering and mathematics (often collectively known as STEM).

A very important, if less obvious, part of the field comprises of classroom teachers who carry research motivated by issues arising in their own science teaching practice. There are barriers to teachers and other professionals making major contributions to the field. An obvious one is time, as busy teachers often have very little capacity to undertake research on top of their teaching and pastoral duties. Teachers may also find it difficult to access research literature, much of which is behind paywalls: although increasingly material is available through open or free access. Another potential barrier is lack of knowledge and skills in research methods - although this is now often recognised as something that should be included in science teacher education.

Furthermore, much research carried out by teachers is context-directed. That means that rather than seeking to explore a major theoretical issue in the field that might apply widely, the teacher is primarily concerned to address an immediate problem or issue in practice: why do these students not 'get' conservation of energy? Why is this class not motivated to study molluscs? How can I teach my students about climate change in a way that is informative, but allows them to make up their own minds about what needs to be done?

Often the teacher's issue or problem would be shared by many others around the world, and perhaps their solution may work elsewhere - but their motivation and focus is appropriately on changing their own practice rather than claiming a new generalisable theory or approach. Often very useful teacher research is of the form (Whitehead, 1989):

(a) recognising I am not happy about some aspect X of the science teaching and learning here;
(b) finding out what existing research suggests might work;
(c) trying out some promising ideas;
(d) finding something that seems to work better to incorporate in classroom practice from now on.

It may be that much context-directed research of this kind offers little that is new to inform other teachers, but it can still make a real difference to students in the specific research context. Some research undertaken by science teachers in their classroom however does offer new ideas and deserves to at least be reported to colleagues at science teacher association meetings and in practitioner journals such as (School Science Review) or more specific disciplinary teaching magazines (such as Education in Chemistry).

What makes a field?

A scientific or academic field is an area of activity having a sufficient level of organisation and coherence to have become widely recognised as an entity. So the field of science education is a social construct - it exists to the extent that enough people considered to be authoritative about such matters (which is itself a matter of social agreement) consider it exists. If a scholarly field is a social construct, it does not exist in the same way that perhaps a tree, or a mountain or the planet Jupiter exist. These things exist as natural objects independently of whether people know of them and how they think about them. Social constructs depend on a kind of social consensus that could disappear.

Type of issue:	Relates to:	Examples from science	Examples from education
Ontological	The nature of things	How should an acid be understood (e.g. Brønsted-Lowry, Lewis model?)? Are atomic orbitals real or just useful fictions? What is dark energy?	What is learning? How is knowledge represented and structured in a person's mind? What is good teaching?
Epistemoglogical	How we know things	Does preparing samples for observation under the electron microscope modify the sample and change what is there to be seen? How can we deduce the existence of very short-lived particles from patterns seen in high energy collider detectors? How can we identify functional groups in organic chemicals from absorption patterns in spectroscopy?	What counts as evidence of learning? When do researcher beliefs and expectations get communicated to teachers and learners and influence research outcomes? Are classrooms that are observed by researchers changed by the presence of the observer?
Axiological	Acting in ways informed by our values	Is it right to induce or breed disease in animals for purposes of medical research? Should scientists undertake research intended to develop lethal weapons? When is it fair to study participants to run clinical trials on unproven drugs to test their efficacy?	When is it fair to teach children using unproven techniques/ resources to test their efficacy? How much do we need to tell people about a study to consider they have given us informed consent? Is it fair to use classes as controls in research when they cannot benefit from the intervention being tested?

Table 2: Research (in science, and in science education) raises questions about (a) the nature of things we might enquire into; (b) how robust knowledge can be constructed; and (c) how we should act in the world.

Moreover, many of the objects of research in education are also social constructs that do not have an independent physical existence. Think about such notions as exemplary teaching, an orderly classroom, a productive group discussion, effective learning, a good classroom environment or a naughty child. Such things 'exist' but how they are understood depends upon the perceptions of those who construe them in particular ways. The child who interrupts learning activities to ask awkward questions may be seen as disruptive and naughty, or as gifted and inquisitive, perhaps depending on cultural or institutional norms. That is, the same child, doing the same things, could be construed very differently. A school science lesson where all the children sit quietly in rows and write down what the teacher says would in some cultural contexts (at particular places and at particular times) be seen as a good lesson, when at other times and in other places this would be seen as unsuitable for promoting effective learning. In some contexts such a classroom would be assumed to be demotivating for the children - but that need not necessarily be the case, as this depends upon children's expectations and the norms they have assimilated.

All research has to engage with issues of ontology (the nature of things that we might investigate), epistemology (how we come to knowledge about those things) and axiology (the values that inform our choices of action in the world). This applies to research in natural science as much as in science education (see Table 2), although because science disciplines are often organised into well-established research traditions (Kuhn, 1996) the novice researcher gets inducted into the shared assumptions of those already working in the field and comes to take much for granted. In educational research these issues tend to be more often explicitly discussed when writing about research.

As research is progressive (that is as what is found out in research today suggests questions for further enquiry), questions that may be considered things to think about when designing research today, may have themselves been the subject of enquiry previously. The ontological and epistemological questions in Table 2 are matters that can be informed by empirical research (and the axiological questions may be explored through philosophical enquiry). To adopt these technical terms, a reader might pose the question that: whilst it might seem a good idea that there should be a field of research to support science teaching (an axiological consideration), if research fields have the rather tenuous status of being socially constructed (an ontological claim), how can we know it is reasonable to talk of there really being a field of science education (an epistemological matter)? This is a reasonable question, but there is a good deal of evidence that the SER field is a meaningful and useful construct for making sense of much scholarly activity (Fensham, 2004). For example, we might take the following as useful indicators:

- There are national and international associations concerned with science education.
- People can take degrees in science education - including both taught and research—based postgraduate ('higher') degrees.

- There are specified posts in the field (such as lecturer in science education; professor of science education) and sometimes university departments of science education;
- There are national and regional research associations specifically concerned with SER (for example the European Science Education Research Association; the Australasian Science Education Research Association; and the National Association for Research in Science Teaching based in the United States)
- There are quite a number of research journals in science education, and a major journal devoted to publishing reviews of research in the field (see the further reading at the end of this chapter)
- Major publishers produce book series in science education;
- There are regular national and international conferences in science education;
- There are established 'handbooks' as key reference works in the field (see the further reading at the end of this chapter)

Such indicators show that much scholarly activity is commonly recognised as an entity, SER. Moreover, just as in the natural sciences (Lakatos, 1970), it is possible to find evidence of specific research programmes within science education (Erickson, 2000; Gilbert, 1995; Solomon, 1993; Taber, 2006) where research topics are addressed over series of studies that adopt the same set of starting points, and build iteratively on each other.

How is research carried out in science education?

According to the historian of science Thomas Kuhn, science is characterised by communities which share a 'disciplinary matrix' - which includes such features as common assumptions, key discipline-specific exemplars, theoretical, methodological and analytical tools. Scientists working in the same field and within related research programmes are likely therefore to agree on core concepts for making sense of the field, general experimental or observational approaches, the kind of instrumentation that is useful and how to analyse data sensibly. So particular techniques (e.g., electron microscopy, high energy particle colliders; genomic sequencing; PET scans, etc.) may tend to become recognised as standard approaches in a field. Knorr Cetina (1999) has characterised the very different ways that scientists work in the two different fields of molecular biology and high energy physics - where the different nature of the subject matter and the consequent epistemological challenges lead to different ways of organising laboratories (and even understanding what a laboratory is), as well as distinct sets of core concepts, core assumptions, and core techniques.

Science education is not as finely structured as many areas of the natural science. Often problems are not as well defined, and researchers may work across a range of problems and kinds of research questions. A wide range of methods are used in science education (National Research Council Committee on Scientific Principles for Educational Research, 2002), and because the phenomena being studied are often complex, it is sometimes considered that methodological pluralism and/or analytical pluralism is needed to address problems - so complementary methods of data collection (National Research Council Committee on Scientific Principles for Educational Research, 2002) and analysis (Taber, 2008) may be used in the same study.

Experimental research in education

Some SER uses experimental methods. A common (but often quite weak) form of educational experiment involves teaching two parallel classes by different methods to see which approach produces the better educational outcomes. There are a number of serious problems with this kind of research design. For one thing there are so many uncontrolled and often unknown variables. Any experienced teacher knows that parallel classes can be very different to teach as every student is unique and classes behave in ways that depend upon the complex interactions between the individual students. Moreover teachers with similar qualifications and levels of teaching experience cannot be assumed to be 'equivalent'. Having the same teacher teach both classes does not solve this challenge as few teachers are equally as skilled at (or committed to) several different teaching approaches. Even such factors as the time of day when classes are scheduled (which may be different for the classes) or the teaching rooms used (different levels of light, noise, arrangement of resources, etc.) can make a difference - although such details are seldom reported in studies.

To some extent these problems can be reduced if research is carried out on a large scale, with many classes randomly assigned to the two different conditions, as most of the incidental factors will (probably) largely cancel out if the sample of classes is big enough. But such studies are difficult to organise (and expensive to resource). They still can not allow for such factors as teacher and student beliefs about which approach is better (expectancy effects that can influence outcomes) or problems of allowing for the novelty of an innovation - which might be motivating for students, or may sometimes seem to threaten familiar routines.

Another problem with many studies evaluating new teaching approaches, curriculum or resources is the tendency of teachers to need to have taught something new several times through with different classes before they become proficient and outcomes reflect the full potential of the approach. Often studies are comparing teachers trying something new with teachers carrying out their normal practice - carefully honed teaching routines. Teaching and learning are complex, and teachers refine their skills over time based on - sometimes subtle - feedback on how students respond to different approaches, sequences, models, activities etcetera. Teachers also develop a better understanding of pedagogies as they reflect on trying things about with a variety of classes, and gradually come to optimise a fit between teaching style; personal repertoire of anecdotes, examples, and teaching skills; pedagogy; local resources; and student characteristics. Evaluations of innovations then often suffer from either being enhanced by the enthusiasm of pioneers, or being handicapped by the unease of seasoned professionals moving out of their comfort zone to work in ways they have not yet been able to practise and mould.

There are also ethical issues to be considered. Children (and teachers) cannot be assumed to be available as research subjects. Rather, participants must offer informed consent to be part of a research project, especially where their talk or written work may be published. Usually when children are involved parental permission is needed before children can be closely observed or interviewed or tested for research purposes.

A particular problem occurs when researchers claim to be comparing some innovative approach (constructivist/progressive/reform-based teaching) with 'traditional' teaching - if traditional teaching involves asking teachers to teach in ways research already suggests are less effective. This may sound fanciful, but it is not unusual to see studies where it is reported that the control class did not involve discussion work, or access to multimedia resources, or hand-on practical work, etcetera, but was restricted to listening to a teacher, reading a text book, and making notes or answering written questions. Perhaps sometimes that genuinely is the typical practice in the research context and so provides a fair comparison condition - but it is not acceptable to set up such a situation in the hope of showing that an alternative approach is more successful, when there is already a great deal of evidence suggesting that this will be the case. This can be avoided by testing innovative approaches against pedagogy that is already recognised to be effective. Rather than ask 'is this approach better than a stereotype of unsatisfactory outdated pedagogy?' the question becomes 'how well does this innovative approach compare with other pedagogies known to be effective?'

Teachers testing out new ideas in their own classrooms often adopt an 'action research' approach where new ideas are tried out, and carefully evaluated, then modified if need be, then evaluated again (as many times as seems appropriate) to inform future practice. The lack of a control or comparison condition limits the inferences that can be drawn from this kind of research, but the teacher-researcher is aware of the provisional nature of their findings, and will not assume that what has worked well with one class will always work well in the future. The attitude here is to adopt evidence-based practice, but to always be open to collecting further evidence. As in science itself, we should always be open to new information that may change our minds.

There are approaches, such as design research and lesson study, that allow teachers to work together, sometimes with specialist researchers, to test out teaching approaches and resources that may be generalisable across classes - at least within certain bounds (in teaching a certain topic; in working with pupils of a certain age; etc.). These approaches also tend to use iterative cycles of research, where repeated modified applications help optimise instructional design or resources. However, the science teacher is in clinical practice in the sense that, like a doctor treating patients, every case is somewhat idiosyncratic. The teacher needs to be alert to the sense in which every new class presents a new test of teaching practice and a potential reason for seeking to develop that practice further.

Alternatives to experimental research

Experimental research is a major tool in the natural sciences where it is often possible to identify, measure and control potentially confounding variables. Educational phenomena are seldom easily subject to laboratory-type testing and researchers in science education have other kinds of research tools more suited to exploring complex phenomena. Researchers can use methodologies such as surveys, case studies, ethnography and grounded theory to develop new knowledge (Taber, 2014).

Surveys sample a population to answer a research question of some generality. For example surveys might be developed to answer questions such as:

- how many years of classroom teaching do science teachers typically have before being made heads of school science departments - and does this vary by gender?
- what proportion of 16 year old students understand the nature of ionic bonding?
- which science topics do primary school children most enjoy?
- how much time is typically given over to group discussion in secondary school biology lessons?
- to what extent do school textbooks offer historical context to scientific discoveries?

- to what extent do students see college teaching about atomic structure (or photosynthesis, or genetics, or…) as building upon, rather than contradicting, school science?

Questions such as these require data to be collected from either an entire population (which is seldom possible) or a sample considered representative of that population. This type of ('nomothetic') research is focused what is usual, normal or typical. Sometimes it makes sense to look for the average or typical in this way, but sometimes research is focused on the complex nature of teaching and learning - with many interacting factors at work - which cannot be easily explored through averages. Here 'idiographic' approaches such as case studies may be used to explore individual cases in great detail, and report them with 'thick description' so the reader appreciates the context of the case. The case is one unique example among many:

- the science curriculum in one country or region;
- the marking scheme for a particular physics paper;
- the presentation of atomic structure in one textbook;
- the teaching of acids by one teacher to one class;
- one student's ideas about the nature of the world at the micro-scale.

Findings may not be generalisable in the sense that they can be assumed to apply in other contexts, but may be informative because they highlight nuances and subtleties that can only be identified through detailed study of individual cases. Sometimes cases are deliberately chosen NOT to be typical, as when an exemplary teacher might be studied to find out what make them such a good teacher. For example, when Karina Adbo interviewed Swedish upper secondary students about their thinking about the chemistry topics they studied in school she chose to report a case study of a student with an atypically rich conceptualisation because this provided particular insight into how a students' initial ideas channelled the way his thinking developed in response to teaching (Adbo & Taber, 2014).

Researchers may adopt ideas and approaches from anthropology if they are exploring a cultural issue. One example would be a book by David Long (Long, 2011) reporting an ethnographic account of how students in the USA responded to scientific ideas about evolution when these were widely rejected in their local communities. Another strategy, grounded theory is a coherent research approach that tests and retests ideas and theory developed in a particular context until there is strong evidence that key issues are well understood. It requires extensive engagement in the research context and an open-ended evolving research design. Unlike in experimental research where samples and instruments and endpoints are determined before starting data collection, grounded theory research lets ongoing analysis of data inform decisions about what new data to collect, and the research continues until this process no longer provides substantially new insights.

These research methodologies then offer diverse types of research strategy. There is also a wide range of specific research methods or techniques adopted in SER, and some of these are used (but in somewhat different ways) across methodologies. For example, surveys may use observation or written instruments. The latter may be questionnaires to survey opinions, perceptions and the like, or assessments (tests) to explore levels of scientific knowledge.

Observation in a survey is likely to use a structured format - with fixed categories and indicators for coding what is seen. Because a case study would normally have a more open-ended research question, observations are more likely to allow the observer to decide what it is pertinent to record. In both cases there is inevitably a level of interpretation in making observations based on what is seen: but in the former case it has been previously decided what indicators are likely to reflect features of interest. In grounded theory studies, research observation may shift from being open-ended to more structured during the research as initial analysis suggests conjectures to test out.

Surveys may use structured interviews, but more often educational research uses less structured interviews where the researcher probes the participant using a more conversational approach. A conversation is less reproducible between participants, but may be needed to find out about the complexity of someone's ideas, especially when they may not have mastered a canonical use of scientific terminology. Much of the work into learners' ideas in science has used more open ended interview approaches. There have new techniques developed for this kind of work, such as the interview-about-instances (Gilbert, Watts, & Osborne, 1985) which used a pack of visual images as foci for prompting thinking about situations ("is there any force here…?") This is an example of a research technique developed in science education which can be used much more widely.

Conclusions

Science education comprises a major area of professional activity concerned with teaching, supported and informed by an active field of scholarship and research. SER is well established as a field, employing a diverse range of research methodologies, and has led to a great deal of knowledge about student thinking, common learning difficulties, effective teaching approaches and so forth - albeit in some science topics more than others. Effective science teachers seek to make sure their work is informed by this research. However, every institutional context has its own quirks, every class is different, and every student is unique. Each teacher has their own strengths, weaknesses and style. So even when relevant research is available to inform our teaching, there is a sense that every lesson is potentially a further field test of the research results we seek to apply. That is something science teachers should appreciate - if they adopt evidence-based teaching, then their professional work takes the form of a personal research programme within the scholarly field of science education.

Further reading:

There are quite a number of research journals concerned with science education. Among the most highly thought of are:

International Journal of Science Education
Journal of Research in Science Teaching
Research in Science Education
Science Education

There is also a journal devoted to in-depth reviews of areas of research in science education

Studies in Science Education

There are also more specialist journals such as

Chemistry Education Research and Practice
Journal of Biological Education
Journal of Geoscience Education
Physics Education

There are also a number of standard reference works in science education that include scholarly articles on a range of topics:

Fraser, B. J., Tobin, K. G. & McRobbie, C. J. (Eds.) (2012) Second International Handbook of Science Education. Dordrecht: Springer.

Gunstone, R. (Ed.) (2015) Encyclopedia of Science Education. Dordrecht: SpringerReference

Lederman, N. & Abell, S. K. (Eds.) (2014) Handbook of Research in Science Education, Volume 2 (pp. 457-480). New York: Routledge.

Matthews, M. R. (Ed.) (2014) International Handbook of Research in History, Philosophy and Science Teaching. Dordrecht: Springer.

An introduction to educational research written with classroom teachers and preparing teachers in mind is:

Taber, K. S. (2013). Classroom-based Research and Evidence-based Practice: An introduction (2nd ed.). London: Sage.

References

Adbo, K., & Taber, K. S. (2014). Developing an Understanding of Chemistry: A case study of one Swedish student's rich conceptualisation for making sense of upper secondary school chemistry. International Journal of Science Education, 36(7), 1107-1136. doi: 10.1080/09500693.2013.844869

Erickson, G. (2000). Research programmes and the student science learning literature. In R. Millar, J. Leach, & J. Osborne (Eds.), Improving Science Education: the contribution of research (pp. 271-292). Buckingham: Open University Press.

Fensham, P. J. (2004). Defining an Identity: The evolution of science education as a field of research. Dordrecht: Kluwer Academic Publishers.

Gilbert, J. K. (1995). Studies and Fields: Directions of Research in Science Education. Studies in Science Education, 25, 173 - 197. doi:10.1080/03057269508560053

Gilbert, J. K., Watts, D. M., & Osborne, R. J. (1985). Eliciting student views using an interview-about-instances technique. In L. H. T. West & A. L. Pines (Eds.), Cognitive Structure and Conceptual Change (pp. 11-27). London: Academic Press.

Knorr Cetina, K. (1999). Epistemic Cultures: How the Sciences Make Knowledge. Cambridge, Massachusetts: Harvard University Press.

Kuhn, T. S. (1996). The Structure of Scientific Revolutions (3rd ed.). Chicago: University of Chicago.

Lakatos, I. (1970). Falsification and the methodology of scientific research programmes. In I. Lakatos & A. Musgrove (Eds.), Criticism and the Growth of Knowledge (pp. 91-196). Cambridge: Cambridge University Press.

Long, D. E. (2011). Evolution and Religion in American Education: An ethnography. Dordrecht: Springer.

National Research Council Committee on Scientific Principles for Educational Research. (2002). Scientific Research in Education. Washington DC: National Academies Press.

Pring, R. (2000). Philosophy of Educational Research. London: Continuum.

Solomon, J. (1993). Four frames for a field. In P. J. Black & A. M. Lucas (Eds.), Children's Informal Ideas in Science (pp. 1-19). London: Routledge.

Taber, K. S. (2006). Beyond Constructivism: the Progressive Research Programme into Learning Science. Studies in Science Education, 42, 125-184.

Taber, K. S. (2008). Of Models, Mermaids and Methods: The role of analytical pluralism in understanding student learning in science. In I.V. Eriksson (Ed.), Science Education in the 21st Century (pp. 69-106). Hauppauge, New York: Nova Science Publishers.

Taber, K. S. (2013). Three levels of chemistry educational research. Chemistry Education Research and Practice, 14(2), 151-155. doi:10.1039/C3RP90003G

Taber, K. S. (2014). Methodological issues in science education research: a perspective from the philosophy of science. In M. R. Matthews (Ed.), International Handbook of Research in History, Philosophy and Science Teaching (Vol. 3, pp. 1839-1893). Dordrecht: Springer Netherlands.

Whitehead, J. (1989). Creating a Living Educational Theory from Questions of the Kind, 'How do I Improve my Practice?'. Cambridge Journal of Education, 19(1), 41-52. doi: 10.1080/0305764890190106