Defining Integrated Science Education and Putting It to Test

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The Swedish National Graduate School in Science and Technology Education, FontD
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Abstract

The thesis is made up by four studies, on the comprehensive theme of integrated and subject-specific science education in Swedish compulsory school. A literature study on the matter is followed by an expert survey, then a case study and ending with two analyses of students’ science results from PISA 2003 and PISA 2006. The first two studies explore similarities and differences between integrated and subject-specific science education, i.e. Science education and science taught as Biology, Chemistry and Physics respectively. The two following analyses of PISA 2003 and PISA 2006 data put forward the question whether there are differences in results of students’ science literacy scores due to different types of science education.

The expert survey compares theories of integration to the Swedish science education context. Also some difference in intention, in the school case study, some slight differences in the way teachers plan the science education are shown, mainly with respect to how teachers involve students in their planning.

The statistical analysis of integrated and subject-specific science education comparing students’ science results from PISA 2003 shows no difference between students or between schools. The analysis of PISA 2006, however, shows small differences between girls’ results with integrated and subject-specific science education both in total scores and in the three scientific literacy competencies. No differences in boys’ results are shown on different science educations.
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1. Integrated versus traditional science education
How can schools achieve skilled students with a good education? The organisation of education is supposed to be important. Is it? If it is, how important is it? Is it reflected in student scores when students with different Science education are compared? This thesis will describe the ideas behind integrated Science education; investigate studies of student results to determine differences between integrated and subject-specific Science education in Sweden and internationally; and provide a short description of integrated Science education in Sweden compared to integrated Science in other countries.

1.1 Science education integration, content and structure
The word integration in the Swedish National Encyclopaedia (Nationalencyclopedin, 2002) is defined as a fusion into a whole, or an arrangement as a natural part of a whole. It comes from the Latin word ‘integrare,’ which means to restore to an unspoiled whole. Integrated curricula have a long history in Anglo-Saxon educational research. It has been possible to search for this keyword in the ERIC thesaurus since 1966. According to ERIC, integration is a ‘systematic organization of curriculum content and parts into a meaningful pattern.’ A related term, unified studies curriculum, was registered as a keyword in 1980 and is defined as 'Curriculum designed to integrate an educational program by eliminating the traditional boundaries between fields of study and presenting them as one unified subject'. The modern idea of integrated education is rooted in ideas from Dewey (1938) about democratic education; the idea was further developed by Hopkins (1940) and by many others.

What is the aim of integrated education? Are subjects integrated? Is the school day integrated? Is the school schedule integrated? There have been some attempts at integrating the school day in Sweden, primarily integration of the school schedule (Westlund, 2003). Westlund demonstrated in a thorough study how schedules scatter time in schools (Westlund, 1998). But is time or the schedule the core issue of integration? Or is it the individual student’s integration of knowledge within himself or herself? Is the goal of integrated education a special way of working, the student’s process or is it the student’s general competency? Is the aim of integrated education a combination of general processes or competencies from several subjects? This is further developed in section 1.1.4

Andersson drew a distinction between different ways wholeness may be created in a Science classroom (Andersson, 2007, p 28-29). Wholeness can be created by teaching students parts that connect to a whole; alternatively the student’s wholeness can interact with the overall wholeness; or students may themselves create wholeness without a clear intent from the teacher. Andersson discussed different kinds of integrated education possible in the Science classroom. Education may be integrated at the individual, content and/or context level in his model of integrated education. Integrated education cannot take place if no one is integrating, according to Andersson.

This thesis will investigate ideas about the current validity of integrated Science education. The theory of curriculum studies in Science and the main ideas discussed in this field are presented. The first part of this thesis discusses ideas about integrated Science education that flourish in the literature, with an eye towards distinctions between different views of integrated Science education. Differences between student results in Scientific literacy and attitudes to Science will be investigated for different groups of students with different Science
educational organisations, i.e. integrated and subject-specific Science education. On the basis of these findings, differences between Science educational organisations are discussed.

1.1.1 A history of integrated Science education

The 20th century in the USA has witnessed a continuous discussion about integrated Science education (Hurd, 1986). Intertwined with this discussion has been a discussion of progressive education based on Dewey’s ideas (Gilbert, 2005). The demand for integrated education reached its climax in 1970 when the U.S. Advisory Committee for Science Education of the National Science Foundation recommended a curriculum that related Science and Technology to human and social affairs (Hurd, 1986, p.356). During the same time period, two large international organisations started a continuous mapping and development of integrated Science education. One of these organisations is UNESCO, which publishes the report series ‘New trends in integrated Science teaching’ and the other is ICASE, the International Council of Associations for Science Education, an association of teacher organisations with the goal of integrating Science education.

One of the first steps in mapping and developing integrated Science education was to find a model for integrated Science. Blum created a two-dimensional model consisting of scope and intensity. Scope deals with the disciplines that are integrated. Intensity has three levels: full integration (amalgamation), combination and coordination. He uses this model to categorize curricula in different parts of the world (Blum, 1973). By 1979, the variety of curricula with integrated Science had grown to such an extent that it became almost meaningless to talk about integrated curricula. Haggis and Adey described the occurrence of integrated Science curricula (Haggis & Adey, 1979a); they also analysed and discussed implementation trends in different countries for integrated science curricula (Haggis & Adey, 1979b). At the same time, Brown wrote about the meaning of integrated education and argued in favour of integration (Brown, 1977). She analysed four themes in the light of a dispute between two writers, Bernstein and Pringe, regarding the differences between and within collected and integrated curricula: ‘unity of all knowledge’, ‘unity of the conceptual structures of Science’, ‘unified process of scientific enquiry’, and ‘interdisciplinary study’.

During the 1980’s, research into integration in Science education occurred at the same time as research into STS. The meaning of integration did not appear to change with the change of words used to describe the phenomena. Aikenhead richly described the emerging field of STS (Aikenhead, 2003). In the USA, there has been a discussion about scientific literacy that involves Science teaching more than integrated Science education (de Boer, 2000). de Boer discusses at least nine separate goals for Science education for the public where STS is one component of the public’s interface with Science. He concludes that the important thing about Science education is that students continue to find Science interesting and applicable to things they experience both in and outside of school. Regarding the debate about scientific and Science literacy, Roberts presents two visions of the aims of Science education: the first vision is that some students will become Science professionals and they acquire Science skills for this purpose; the second vision is that all students need scientific literacy to become fully-fledged citizens able to work with and learn about science related matters in their professional and private spheres (Roberts, 2007). This is an echo of earlier writers, e.g. Fensham (1985).
1.1.2 Integrated Science education

The Science education community expresses different views about how Science education should be organised. The relative merits of integrated versus subject-specific Science in compulsory schools are disputed among teachers, scientists and teacher educators. Here we will describe these disputes and the alternative standpoints regarding Science education and integrated Science education. A thorough description of these points of view and their different positions may be found in Fensham (1992). Fensham gives a comprehensive description of a problem area in Science education. First, Fensham points to the social changes of the 1960’s that gave Science new groups of learners, with all the difficulties this entailed. One interest group, consisting of concerned Science teachers, expressed difficulties in satisfying the interests of the different students in the Science classroom. Another interest group, Science educators as a professional group, worked with curriculum development and later worked in academic or advisory positions. Yet another interest group, academic scientists, maintained that the number of students applying for higher education in their departments was insufficient to cover the departments’ needs. Fensham describes setbacks in implementing the new curriculum during the 1980’s in his essay from 1985 (Fensham, 1985), where he charts major problems with Science content. In his words:

‘After all, two of the things that mark off many Science teachers, scientists and most Science curriculum developers from the great majority of their peers are their interest in scientific knowledge as such and their willingness to persist in its learning. It is neither surprising nor unnatural that persons educated extensively in Science should look at the world, and at schooling, through eyes that are conditioned by scientific knowledge. This, however, means that what they see as important, significant and worthy of learning is likely to be different from what persons uneducated in Science see when they look to Science as a phenomenon in their lives and in society.’ (Fensham, 1985, p. 421)

The point here is not that everyone should share similar views on what is important, but that scientists and Science teachers have different views regarding what is worth knowing of science and knowing in science. Fensham’s lodestar, as discussed by Wandersee, is that Science teaching must be ‘of actual use’ to the student group in both an affective way and in a real-world context (Wandersee, 2003). This has been jeopardised by how curriculum implementation is conducted, since Science in secondary schools has had a preparatory character and this affects how Science is defined in the early school years. Science subjects have helped select students with the commitment and persistence needed to perform well in this type of learning. The way Science curricula were updated in the 1960’s made secondary science education like a less advanced copy of Science studies at universities. To overcome subject difficulties, elementary school Science and secondary school Science created a division of labour such that elementary schools taught ‘processes of science’. In elementary schools, many teachers were not educated in Science during their teacher training and Science had a nominal place in school.

‘Many elementary teachers found that they could teach them with more personal comfort, and with apparently greater effectiveness, in relation to social phenomena in other areas of the elementary curriculum’ (Fensham, 2002, p. 11).

This sublimated the content of Science in the lower grades and students did not get accurate Science education in lower grades, according to Fensham.
Roberts gives us a description of the desired outcome, calling them *visions I* and *II* (Roberts, 2007): *vision I* is Science for further studies in Science and *vision II* is Science for informed citizens. Formalisation of these visions in English-speaking school systems has involved offering specific Science courses for students who plan to continue to higher Science education and general Science courses for students without such plans. This leads to specific problems like disinterest from students and difficulties in changing courses later on. Fensham et al. gives us their view of how to alter this situation in school. This is done from international studies and a constructivist view of learning (Fensham, Gunstone, & White, 1994). The authors name three factors that necessitate change in Science education: *the variety of Science content*, *the complexity of Science content* and *Science in action*.

Returning to the debate over integrated Science education, Lederman and Niess presented their views (Lederman & Niess, 1997). They begin by defining integration and alternative ways of organising Science education. They point out the distinct boundaries of each discipline, what they call discipline integrity. They maintain that teachers cannot learn everything they need to know in each discipline to teach integrated Science at all levels. They define integrated, interdisciplinary and thematic curricula and claim that these three ways of organising curricula are different. One of Lederman’s definitions is:

> ‘Integration refers to a combined or undivided whole. [...] In curriculum/instructional integration, the different subject matters form a seamless whole. [...] The term interdisciplinary stems from the Latin preposition inter, meaning between or among things or parts. [...] In an interdisciplinary curriculum/instructional approach, the integrity of the various academic disciplines remains clear. No attempt is made to "blur" the distinctions between and within mathematics and the sciences. [...] Thematic pertains to unifying or underlying commonalities among subjects or topics. [...] The most familiar themes to educators are problem solving, critical thinking, and decision making.’ (ibid p. 57)

In conclusion, Lederman writes,

> ‘Finally, although arbitrary, the academic disciplines have developed over the years in response to the expansion of knowledge. However, the arbitrary nature of disciplines is not a justification for the destruction or elimination of disciplinary boundaries. Every discipline possesses characteristics that are clearly unique to that discipline. Integrated and thematic curriculum/instructional approaches ignore the conceptual, procedural, and epistemological differences that exist between the various areas of mathematics and the sciences. For example, problem solving is quite different among the various sciences let alone across mathematics and science in general. Within an interdisciplinary approach, the unique and valuable aspects of the various academic disciplines can be maintained while still developing students’ understanding of interconnectedness.’ (ibid p. 58)

Lederman’s definitions of integrated, interdisciplinary and thematic curricula are comparable to Blum’s (Blum’s intensity dimension is developed in section 1.1.3).

As can be seen from this discussion among three prominent Science educators, both the outcome of students’ learning and the content of subjects are at stake in this discussion. The outcome of students’ learning can be either Science of use for further studies, Science of use in adult life, or Science of use in future workplaces, either scientific or non scientific. The
subject content is more vaguely sketched, and content can be organised in several ways, as will be described below. With the above as a background, there are several ways to organise integrated Science education. 1) ‘Concepts in Science’: this involves presenting general concepts in Science together with demonstrations of how different disciplines interact with these concepts. An example of this is the concept Energy, which may be studied from the perspectives of Chemistry, Physics and Biology at different school levels. 2) ‘Science in Contexts’: another approach for integrated Science education is learning in a Science context environment, where learning takes place through problem-solving and projects. This is Science in Contexts, although a more common name is problem-based Science education. 3) ‘Concepts in Context’: this third alternative is a combination of general concepts in a Science context. A picture of the different slogans for integrating Science education and their relationship to the outcomes scientific literacy and public understanding of Science is found in Figure 1.1. This section of the thesis will discuss these different slogans of integrated Science as mechanisms of learning that lead to scientific understanding (see section 4.1 where the concept of mechanism is discussed). The ideas behind these slogans of organising integrated Science education are dealt with and the STS movement is presented in this section.

**Figure 1.1** Variations of integrated Science education and possible outcomes

A fourth slogan of integrated Science education is formulated by an international movement in Anglo-Saxon countries called STS. STS’ aims and ideology were developed by Cozzens (1990): ‘Interdisciplinary means integration of fragmented knowledge bases, and that is a significant part of the ideal of STS Thought’. One main idea of STS is to integrate different questions taken from society or the political sphere in order to motivate students to learn Science concepts. The origin of STS is concisely described by Aikenhead (2003). A quotation that summarizes the origin of STS is:

‘For future citizens in a democratic society, understanding the interrelationships of Science, Technology and Society may be as important as understanding the concepts and processes of Science.’ (Gallagher, 1971, p 337)
More than just a melting of different subjects, the idea behind STS is to bring students’ Science education - in higher education as well as in compulsory schools - closer to their needs as members of an increasingly technological society (Fensham, 1988a). Yager is also involved in the STS movement. He writes:

‘The STS approach is one that necessitates problem identification by individual students and individual classes. Such problem identification includes – by its very nature – a multidisciplinary view. There are few problems that are related only to Science – certainly not to one Science discipline’ (Yager, 1996, p. 18).

Yager and Lutz boil the entire question of integration down to a question of “How” versus “What” (Yager & Lutz, 1994). They conclude that “how” Science is taught is as important as “what” it teaches. Fensham is on the other hand very particular that the “what” is as important as the “how” (Fensham, 1988a, 1988b). A definition of context based Science found in the Thesaurus states,

‘The impact or consequences of an encompassing situation on the functions and performance of something -- in education, the effects of situational variables (e.g., physical setting, psychosocial condition, expectations) on perception, cognition, and experience’. (Thesaurus, ERIC database)

Yager, referring to the NRC standard team, claims that contexts of Science is a fourth and final consideration for developing standards, along with Big Ideas about Science, teaching about the Nature of Science, and Applications of Science (Yager & Lutz, 1994).

‘Unfortunately, however, no work has been done in this area. It remains as a fourth and, therefore, final consideration. Concepts remain first order, process skills second, and the necessity to move students to the applications level remains as third. […] The constructivist perspective for learning suggests that context is the most important aspect for determining whether or not learning will occur. For many students, the context for science is the place to start; context can provide the focus on “how” that has been so elusive with all past reform efforts. Considering context implies a focus on student prior experiences. ’ […] ‘Starting with concepts promotes continuation of the focus on “what.”’ (ibid p.342-343)

The last part of the quotation above leads us to the next concept in this presentation. A European example of educational systems that have worked with ‘Concepts in Context’ may be found in the Netherlands’ compulsory school system (Eijkelhof & Kortland, 1988). Andersson performed research and development in the area of ‘Concepts in Context’ for Science education where interpretation of interdisciplinary Science has been done in Sweden (Andersson, 1994b, 2001). Andersson deals with natural sciences in the context of problems in the natural and social environment. Andersson adheres to a social-constructivist view of learning and develops several concepts in Science (adapted to Swedish circumstances) in the latter report. Andersson (1994a) has also discussed integrated Science education from a Swedish perspective, where integration is presented as a developmental project for schools ‘to connect different parts to a whole’, from the individual’s perspective. ‘The teacher can facilitate integration, but at the end of the day it is the student who constructs the entirety.’ (Andersson, 1994b). He discusses various kinds of simple integrated Science education: categorical (e.g. a bicycle, a car and a train form a new whole for the individual – vehicles), spatial (e.g. the town Nacka lies just north of Stockholm and Södertälje just south of
Stockholm; a whole is created out of the parts Nacka, Stockholm and Södertälje with the help of a reference system, temporal (fitting separate events into the flow of time) and causal (e.g. tracks in snow and a cat’s paws are integrated into a causal relation: a cat walking through snow). He also treats more complex forms of integration, such as theory integration, causal chains or webs, orientation systems and problem-focused integration (Andersson, 1994a). In a later text he writes that integrated teaching and integrated learning is not a simple relationship (Andersson, 2007). Teachers who integrate may not attract attention that integration is needed from students.

Schwab is one of the earliest writers on the nature of natural sciences. He discusses the differences in views of different subjects. An example of this is the structure of an atom viewed from the perspective of Chemistry and Physics: the object studied is the same, but the focus of interest varies from the different subjects. He also makes an important point about knowledge of subject structures

‘In curricular terms, this means that knowledge of the structure of history, mathematics, and science does not enable us to organize either knowledge or the curriculum. This is not to say that clarity regarding the structure of mathematics is unimportant, but that to the curriculum builder such clarity is insufficient for his task.’ (Schwab, 1964, p.3)

Schwab writes about ‘substantive structures of natural sciences’ (ibid p. 46) and discusses reductive, ‘organic’, ‘holistic’ and rational scientific principles. These are, in his opinion, distinctly different ways of looking at Science and Science content. Schwab’s writing indicates that different subjects in Science are distinct from each other. He mentions specifically Physics, Biology and Chemistry. According to Scriven, this kind of distinction does not apply to the Social Sciences (Scriven, 1964). He claims that Social Sciences are constructed from History, Geography and Psychology. These subjects are strung together by means of logic, Mathematics and methodology. Economics, Anthropology, Sociology and Political Science supplement this field of study. Ethics brings all the subjects together in social action. Scriven maintains that no single subject in the Social Sciences is independent of the others and can stand on its own. His view of the Social Sciences is substantially different from Schwab’s of natural science. One wonders when reading Schwab if it is possible to integrate Science subjects at all. From psychology research about intelligence Detterman presents us with the following: In his opinion, intelligence is a finite set of independent abilities operating in a complex system. Measuring intelligence involves complex measurements which reflect many simpler processes of system function. An index of a complex ability indicates efficiency of the basic, theoretically independent sub-processes which contribute to the operation of the system. Complex measurements are surrogates for more basic processes (Detterman, 1986).

A group in Australia has suggested that it may be erroneous to discuss subjects as a norm and integration as a change process and a product of change (Venville, Wallace, Rennie, & Malone, 2002).

‘We came to the conclusion that integration is a particular ideological stance which is at odds with the hegemonic disciplinary structure of schooling. A leap in understanding for us was the realisation that even the word “integration” implies that the “normal” state of a curriculum is a disciplinary format and that to integrate is a step beyond that status quo’ (ibid, p. 46).
Venville et al suggest that Science education should be treated as World Science. Other works by them regarding integrated Science display traces of Blum’s intensity dimension (Wallace, Sheffield, Rénnie, & Venville, 2007; Venville, Wallace, Rennie, & Malone, 1998); their view of what integration comprises is very inclusive.

To summarise this section regarding integrated Science education, there are at least four ways to look at integrated Science nested with four common research questions: how, what, why and for whom integrated Science should be and become. I have given a short review of four ways the organisation of integrated Science education is discussed in the Science education community, but a word of caution should be applied here. This review has only skimmed the surface of the immense literature in this area and there may be omissions in these descriptions. The four categories of Integrated Science have no simple relation to the three student outcomes of learning found in Figure 1.1. Scientific literacy has been discussed since the early 1930’s. ‘Public understanding of Science’ has been a large movement in Great Britain, and ‘Science for all’ is the Australian slogan for what student learning aims to achieve. However, the relationship between what sort of integrated Science education that would result in one or the other outcome is still disputed. The four views of integrated Science education (Concepts in Science, Science in Contexts, Concepts in Context and STS) do not provide a means of comparing and scrutinising Science integration. Therefore the next section will present a model for comparing Science integration between curricula. This model will be applied to some forms of Science education as it is presented in the literature.

1.1.3 Interdisciplinary or trans-disciplinary integration?

Integrated Science education, as discussed above, deals with ideology and carries within it a tension regarding how to integrate and what sciences to integrate. Yet the discussion of ideology in itself doesn’t provide an instrument to compare different kinds of integrated Science education. Such an instrument must be found elsewhere. Integration of Science may occur within a subject or between subjects. This in turn can be subdivided into integration into a single Science subject, integration within different Science subjects and integration between Science subjects and subjects outside the sciences. An early attempt to schematically present integration between subjects, within subjects and the intensity of integration was made by Blum (1973). Blum’s intensity dimension is divided into three levels where amalgamation is the most fully integrated level and coordination is the least integrated level. Amalgamation occurs when an interdisciplinary topic forms the unifying principle at the chapter level. Coordination exists when independent programs are taught simultaneously. The combined level of integration occurs when chapters of major units are organised around headers from the different disciplines. Blum relates six levels of scope, which in this paper have been simplified to five, since there was no point in separating close natural sciences and all natural sciences in this investigation. School Science subjects are not distinct enough at the end of compulsory school.

Blum’s definition of scope and intensity of integration has been used to analyse three different attempts at defining and discussing integration in the literature. Two of these are the ideas of integration sketched by Brown and Aikenhead, in the case of Brown an early attempt at defining and understanding integration. Aikenhead drew some implications of STS content.

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2 Within one of natural science, between two close natural sciences, between natural sciences, between basic and applied sciences and technology, between natural science and social studies and between Science and the Humanities

3 The categories between two close natural sciences and between natural sciences have collapsed into one category.
The third is the empirical work done in Australia by Venville et al., who made empirical studies of integrated Science in practice in Australia. Finally, Blum’s schedule of intensity and scope is used when the conceptual framework of PISA\(^4\) 2006 is assessed and analysed, in section 2.2.2.

We will first analyse Brown’s ideas regarding integration (Brown, 1977). She writes about the meaning of integrated Science and presents arguments for it. Four conceptual arguments for integrated Science are put forward by her; Unity of all knowledge, Unified process of scientific inquiry, Unity of the conceptual structures of Science and Interdisciplinary Science, and they have been placed into Blum’s categories. The results are available in Table A1.1, Appendix A. This analysis shows that Brown’s description of integrated Science only deals with the more intense parts of Blum’s categories, i.e. amalgamation or combination. At the time that Brown was writing, Bernstein’s ideas about collected code may not yet have impacted on thinking regarding integrated versus subject-specific Science education. Bernstein’s collected code could also be interpreted as a way of piecing together Science to meet the specific content needs of school work: this involves working with a concept in Science and then exploring explanations of this scientific concept in different subject areas. When viewed in this way, Bernstein’s collected code may be placed in category 1 (Concepts of Science), as presented in section 1.1.2. Brown’s paper regarding integrated Science involved interdisciplinary Science in basic/applied Science and Technology, Science and Society and Science and the Humanities. This may be an unfair categorisation, since Brown does not make clear distinctions between these areas and it is possible that too many of Blum’s categories are labelled interdisciplinary in Table A1.1.

An important issue in international research literature deals with the integration of Science and society. One person who has been at the forefront of this work is Peter Fensham in Australia (Cross, 2003). Peter Fensham worked with the slogan ‘Science for all,’ which implies that important social questions with a scientific aspect should be studied as part of the curriculum (Fensham, 1985, 2000). Another slogan dealing with social questions within Science is STS. This work developed during the 1980’s and, like many other slogans working with integrated Science education, there are different ideas about what the content of STS really is (Aikenhead, 2003). Aikenhead sketches eight categories of STS in school Science 1) motivation by STS content 2) Casual infusion of STS content 3) Purposeful infusion of STS content 4) Singular discipline through STS content 5) Science through STS content 6) Science along with STS content 7) Infusion of Science into STS content and 8) STS content. Aikenhead describes a hierarchical relationship among these categories:

‘a dramatic change in content structure occurs between categories 3 and 4. In category 3, the content structure is defined by the discipline. In category 4, it is defined by the technological or social issue itself (learning canonical Science on a need-to-know basis). Interdisciplinary Science begins at category 5.’ (Aikenhead, 2003, p. 66).

Using Aikenhead’s description, the first three categories of STS do not correspond to what Aikenhead would call integrated Science education; they are instead a hybrid form of subject-specific Science with a smattering of social questions to further motivate students. Aikenhead’s category 8 seems to correspond to Blum’s category of amalgamation. As can be seen in Table A1.2 in Appendix A, Aikenhead’s categories of STS do not encompass Blum’s categories of integration, unless the content itself encompasses ‘basic/applied Science and

\(^4\) PISA is the Programme of International Student Assessment, a project implemented by the OECD.
The difference between Science and Technology may have been too narrowly defined here, which is underlined by the fact that the border between Science and Technology is shifting. In the 1960’s, separating Science from Technology was not an issue; however, the difficulties met in establishing Technology (or Design) as a school subject in its own right have given rise to questions dealing with the position of applied Science in schools, i.e. whether applied Science should be a subject separate from the other Sciences or if it is a part of other Science subjects taught by the same teachers.

Venville et al., in a study of sixteen schools with integrated Science education in different settings in Australia, have discussed different kinds of integration. They describe different ways of integrating Science education without differentiating between interdisciplinary integration and integrated education within a discipline (Venville et al., 1998). Their integration categories are assembled according to Blum’s categories in Table A1.3 in Appendix A. This table shows that Venville et al. did not find examples of integration in all of Blum’s categories, assuming that the comparative table is correct. For example, the field ‘Coordination’ in the column ‘Within subject’ is empty, as is the field ‘Amalgamation’ in the column ‘Basic/applied Science and Technology’; all of the fields in the column ‘Science and the Humanities’ are empty of Blum’s predicted intensities. On the other hand, other categories of integration have more than one example of a single intensity and scope. Venville did not find integration between Science and the Humanities in her study, but most other types exist. As in the earlier table, it may be that the boundaries between Science and Technology were not properly defined. A more thorough knowledge of Australian curricula would be necessary to make these distinctions in an Australian context.

In 2007, the group around Venville performed a second analysis of the schools they had worked with in the earlier study and re-analysed and renamed the different types of integrated education found in the schools (Wallace et al., 2007). In this later work, Blum’s dimension of intensity is apparent in the categorisation, with some exceptions. The re-analysis only presents six integration types or categories: synchronised, cross-curricular, thematic, project-based, school-specialised and community-focused.

### 1.1.4 Integration of general competencies

A central issue in the debate between proponents of integrated and traditional Science education deals with whether or not subject-specific education makes it impossible to achieve the general competency of ‘learning-to-learn’, which is one of the desired outcomes of educational efforts. In this respect, learning is motivated by the needs of a knowledge-based society. This society is described in the following manner:

> ‘Knowledge societies are not societies that value knowledge more than other societies. All societies value knowledge. Nor, as some people seem to think, are knowledge-based societies those that need more people who know a lot – in the traditional sense. Rather, they are societies in which people see knowledge in economic terms, as the primary source of all future economic growth.’ (Gilbert, 2005, p.25, italics in original)

This is exemplified in the PISA 2006 main report, Box 1 (OECD, 2007, p. 33) where non-routine analytic and interactive work that needs higher education increased considerably while routine cognitive and manual work that does not need that much education decreased to a similar extent between 1960 and 2000, the year the study took place. This particular study concerned work opportunities in the USA.
A complement to integrated education is the idea of generalised competencies or problem-based experiences in schools (Gilbert, 2005). The author writes about problem-based school instruction based on Dewey’s model, in which ‘education should be a set of integrating, unifying experiences’ (Gilbert, 2005, p.84). Is this view opposed to subject-centred Science as it is taught in schools today, or is it a complement necessary for understanding and learning Science?

A conventional idea about how experts’ versus novices’ knowledge is organised is that ‘Experts’ thinking seems to be organized around big ideas in [physics], such as Newton’s second law and how it would apply, while novices tend to perceive problem solving in [physics] as memorizing, recalling, and manipulation equations to get answers.’ (Bransford, Brown, Cocking, Donovan, & Pellegrino, 2000).

There seems to be a higher degree of generalisation in the experts’ knowledge, according to this statement, compared to the mechanical memory exercises of novices’ knowledge.

Bransford et al. by also comparing experts with novices in problem solving, found that experts arrange the problem solving according to principles that can be applied to solve the problems, and novices arrange problem solving according to the problems’ surface attribute. This can be a fatal strategy, since the surface attribute can confuse the student and make it impossible to find a proper solution, since the problem solving solution might be entirely different in the different problems.

Fogarty (1991) promotes integration both within and between subjects, including integration with multiple intelligences. Fogarty describes ten ways of integrating curricula. To begin with, she states that integration may be within a single discipline; across several disciplines; or within or across a group of learners, thus creating three main groups of integrated education. Separating these three main groups into categories, the single discipline group subdivides into three subgroups; the group that stretches across several disciplines subdivides into five subgroups; and the group within or across a group of learners subdivides into two subgroups. Integration within a single discipline can be fragmented, connected or nested. Integration across several disciplines can be sequenced, shared, webbed, threaded or integrated. Within or across learners, integration can be immersed or networked. Fogarty’s models of integrated curricula are both interdisciplinary and transdisciplinary. Fogarty develops her idea of ten models of integrated curriculum later in a teacher instruction (Fogarty, 1995), where she combines Howard Gardners’ seven intelligences with these ten methods of integration.

A different angle on student learning deals with difficulties of transfer. Transfer occurs when a student has learned something in one context and applies these learned skills or knowledge in a different context. There are different forms of transfer: lateral and vertical, specific and nonspecific, near and far, literal and figural. Lateral and vertical transfer were differentiated by Gangné in 1965. Vertical transfer occurs when a skill or knowledge learned in one situation directly influences learning of a more complex skill or acquisition of more complex knowledge at a later time. Lateral transfer does not involve differences in complexity.

Specific transfer occurs when similarities are observed between things learned in one situation and another situation. Nonspecific transfer occurs when the two situations lack similarities. Near transfer occurs when there is a great deal of similarity between the original learning and the transferred learning. Far transfer was thought to be some generalisation gradient that still
will activate an earlier learned response. Later this was expanded to the ideas of real world problems that could be solved through the use of mathematical operations. Literal transfer occurs when it is possible to apply a bit of knowledge intact from one learning to a new learning area. Figural transfer occurs when metaphores and similes are used (Mestre, 2005). The phenomenon of transfer is prevalent in modern literature on work activities. A problem arises when

‘Students leaving an educational institution and entering a workplace are not carrying ‘transferable’ packages or structures of general knowledge and skills which can simply be activated in the new setting’ (Engeström, 1996).

1.2 Subject-specific (traditional) Science

Science education that is not integrated is usually called traditional (Hirst & Peters, 1970) or textbook Science (Yager, 1968). Aikenhead describes traditional Science as canonical Science. He rephrases the debate about traditional versus integrated Science into one about a humanistic perspective in Science education as opposed to a traditional perspective on Science education. Aikenhead’s description of the traditional curriculum includes a core which deals with

‘canonical abstract ideas […] most often decontextualized from everyday life but sometimes placed in a trivial everyday context. […] emphasis on established Science only. […] Mono-Science approach founded on universalism (Western Science). […] Solely scientific reasoning using scientific habits of mind. […] Seeing the world through the eyes of scientists alone.’ (Aikenhead, 2006, p. 3).

Fensham seems to express another definition of subject-specific Science: a specific content learned for the sake of use in a laboratory for scientific purposes (Fensham, 1985). He sees a number of problems with the Science curriculum:

‘a) it involves the rote recall of a large number of facts, concepts and algorithms that are not obviously socially useful b) it involves too little familiarity with many of the concepts to enable their scientific usefulness to be experienced c) it involves concepts that have been defined at high levels of generality among scientists without their levels of abstraction being adequately acknowledged in the school context […] d) it involves an essentially abstract system of scientific knowledge, […] e) it involves life experiences and social applications only as exemplary rather than as the essence of the science learning f) the role of practical activity in its pedagogy is associated with the belief that this activity enhances the conceptual learning rather than being a source for the learning of essential skills g) its content gives a high priority, even in biology, to the quantitative […] h) it leaves to the continued study of these disciplines at the tertiary level the balance, meaning and significance that is lacking in a-g’ (ibid p. 419).

Fensham (1985) suggests that many of the things seen as problems in the Science curriculum may be resolved by changing the curriculum to one that is student centred and where learning is applied to real world problems and experiences from the students’ perspective (Aikenhead, 1994b, 2003; Fensham, 1995, 2002; Venville, Rennie, & Wallace, 2003).

A shorter and more easily assessed view of the problem of disciplinary knowledge is found in Beane:
‘Part of the reason is that the problem is not with the disciplines of knowledge themselves but with their representation in the separate-subject approach to the curriculum. Put another way, the issue is not whether the disciplines of knowledge are useful, but how they might appropriately be brought into the lives of young people. And more than that, do they include all that might be of use in the search for self- and social meaning?’ (Beane, 1995).

Beane claims that subject-specific approaches to school learning are too narrow to tackle everything a young person needs to know but at the same time, learning without disciplines is too narrow; both methods need to be present.

A review of common Science textbooks for compulsory schools provides some insight into the traditional approach to teaching. Schwab gives us a description of traditional textbook formulation of the scientific method in five steps 1) noting of relevant data 2) forming of a hypothesis 3) plan for test of the hypothesis 4) execution of the plan 5) drawing of the conclusion for the data (Schwab, 1964, p.32). This is similar to descriptions of scientific inquiry preferred by current curricula in the USA. Schwab’s interpretation of scientific method is not as traditional as it may seem, since he discusses the problem of drawing conclusions as a procedure of examining what may be said based on the data generated by study. Schwab’s interpretation means that a particular outcome may prove a hypothesis to be true, but an absence of outcome does not disprove a hypothesis. This interpretation is far from the attitude of ‘one true answer’ that traditional Science education is commonly accused of.

Examples of how integrated and subject-specific Science are described in Sweden may be found in Marklund (1983). Marklund sees an opposition between formal (theoretical) education and practical training, between subject-focused and student-centred learning and between orientation and advanced levels. These pairs of opposites are debated in Swedish curricular discussions. Subject-specific Science in Sweden would thus be formal (or theoretical), subject-focused and at an advanced level, although these are not the only properties of subject-specific Science in Sweden. Bernstein contrasts integrated and collected curricula. Bernstein’s collected curriculum seems to be a form of subject-specific curriculum (Bernstein, 1975), as long as the collection is not intended to create a whole out of the different parts of Science, as occurs in education in concepts of Science. Hirst contrasts integrated and traditional teaching. Hirst’s traditional curriculum seems to bear a resemblance to subject-specific curriculum (Hirst & Peters, 1970). Wennberg deals with the way different actors affect schools in a Swedish context (Wennberg, 1995). In an early work he wrote about the forces behind two school reforms in Sweden (Wennberg, 1990). A description of two views of Swedish school politics appears in this work that can be referred to as integrated and subject-specific teaching views. We find progressives who want to work in projects and themes and others who represent traditional subject teaching.

For this thesis, subject-specific Science means the separate subjects of Biology, Chemistry and Physics. The descriptions of Bernstein and Hirst are relevant in this context. Subject-specific Science is the traditional way of teaching Science in Swedish lower secondary schools. Hirst’s traditional curriculum is presumed when referring to subject-specific teaching. Bernstein writes about subjects with strong boundaries and in Sweden this is applicable to subject-specific Biology, Chemistry and Physics. In the empirical work described in sections 6 and 7 of this thesis, we will find some interesting anomalies in how teachers and experts consider integrated as opposed to subject-specific teaching in Sweden.
Another view associated with Science education is described in Roberts (1988). He writes about curricula from four different perspectives (Science, learner, teacher and society). In his analysis, different viewpoints appear in different categories. Roberts points out that ‘[there is a] difference between educating a Science teacher and winning an ideological convert’ (ibid p.50). According to Roberts, Science education is often dogmatic and doctrinaire even though the content may only be one professor’s views. This might be confused with a subject-specific view, since a professor often has a subject to protect and teach. A learner might confuse a teacher’s dogmatic and doctrinaire view with the subject’s content. If the learner does not succeed in distinguishing between the teacher’s subjective view and the organisation’s perspective, the organisational perspective may be rejected for subjective rather than logical reasons.

1.3 Integrated Science education in the Swedish school system

The question of how to organise Science education has been a matter of debate in Sweden. During the 1980’s discussions dealt with how to grade students in Science. In 1982 the school law was altered so that students received a single grade for all Science subjects. Teachers from an academic tradition opposed this and demanded subject-specific grades. The Agency of Education appointed a commission to look into this issue. The commission concluded that schools should be allowed to achieve curriculum goals any way they want but since goals are formulated in terms of Science, only one grade may be given. This led to a heated debate that ended with a decision to allow schools to choose between two grading systems: either to grade students in Biology, Chemistry and Physics or to give them a single grade in Science (Andersson, 1994a; Riis et al., 1988).

A second debate started with the reform of 1994 with a discussion of whether or not Science should be integrated in all compulsory schools. Englund and Östman feared that the new curriculum with separate subjects in Science would rule out integration and the democratic work accomplished in the earlier school system, in which Science and Social Science were integrated to an increased extent (Englund & Östman, 1995).

1.3.1 Studies of the occurrence of integrated Science in Sweden

In the SIMSS study of 1982, teachers answered a question about integrated Science teaching in Sweden. About 40 percent of teachers in lower secondary school answered that they sometimes or seldom taught Science in an integrated way. Sixty percent answered that they never taught integrated Science. In a subsequent open question, teachers could freely express their opinions on different things. On the basis of those answers, the researchers concluded that Science teachers are unwilling to teach integrated Science (Riis et al., 1988).

In the Swedish National Evaluation of 1992, school teachers were asked what kind of grade they gave students. About 20 percent gave Science grades and 80 percent gave separate grades in Biology, Chemistry and Physics. The National Evaluation assesses different concepts in Science divided into Biology, Chemistry and Physics. Researchers found that students with subject-specific grades did not score significantly higher than students with integrated grades in the three Science subjects. Comparing other school subjects (Mathematics and foreign languages), no significant differences could be determined between students who received integrated Science education grades and those who had subject-specific grades. It was noted however that students with subject-specific grades more often applied for

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5 Second international mathematics and science study
a Science program in upper secondary school than students with integrated grades. Students with integrated grades were on the other hand more confident and satisfied with their lessons and felt that they had learnt more (Andersson, 1994a).

A five year national project in Sweden focussing on using no set timetable has generated several reports on how schools participating in this project implemented this. Alm (2003) studied schedules for 326 schools from grades 1 to 9 in the compulsory school system. He classifies timetables in five levels, ranging from type 1 (with only alternative names of school work) to type 5 (where most lessons have subject names). In schools with ‘type 3-tables’ about half of the schools taught using themes. This type of schedule is most common in grades 1-6. Themes or thematic studies are found in about one fifth of the schedules studied and are statistically significantly more common in grades 1-3 (ibid, p 43). There are as many themes in the schedules of grades 1-3 as there are in grades 4-9 together.

### 1.3.2 Integrated Science education in previous Swedish curricula

Riis has written about integration in the Swedish curriculum through the reforms of 1948, 1955, 1962, 1969 and 1980 (Riis, 1985). She discusses the forces that drive subject division and identifies factors such as social sectorisation and atomisation of knowledge. She discusses four perspectives of integration: ideology, theory, personal integration and integration into everyday life. Concerning the factor ideology, Riis wrote that religion played a major role in this area in early curricula but was later supplanted by democratic ideology in the 1960’s. Regarding theory, she pointed to scientific objectivity as a motive force together with economics.

One part of the curriculum from 1980 (lgr 80) concerned the school day and time spent by students in school (Skolöverstyrelsen, 1980, p. 20). The concept of theme work was used in this context, not as applied in particular to teaching organisation but in the context of other school activities. This was a particular form of integration for students.

Another form of integration involved individually chosen themes within a subject. Work material and work organisation included visits, textbooks, newspapers and experiments. The time to work on a theme was taken from a subject’s total time (ibid, p. 29). Thematic studies of this sort were compulsory in grades 7-9 and on average 4 student hours per week during the three years were to be spent with themes in these grades. Theme planning was strictly regulated in the curriculum and it was planned in great detail by the work unit, so the headmaster would be able to create schedules as needed.

‘The content of a theme shall be in the frame of the main objectives in a subject or subjects. [...] If the students and teachers wish, the work can be subject integrated. [...] Different themes should be treated during a school year.’ (ibid, p.35-36, my own translation).

What exactly a theme consisted of and how students worked with themes was up to the teachers themselves.

### 1.3.3 Integrated Science education in the current Swedish curriculum

A national curriculum for compulsory school was established by the Ministry of Education in 1994. The curriculum describes the responsibilities of the schools and various authorities. It contains a general description of what schools must accomplish. The curriculum points out that students must be able to manage new and changing situations by learning new skills and
using them in changing situations. Students must know history to predict solutions to problems. Students must learn problem solving and be able to work independently (Utbildningsdepartementet, 1994a, 1994b, p.7).

This view of knowledge is based both on subject-specific and integrated thinking:

‘Knowledge is a complex concept which can be expressed in a variety of forms – as facts, understanding, abilities and accumulated experience – all of which presuppose and interact with each other. The work of the school must therefore focus on providing scope for the expression of these different forms of knowledge as well as creating a learning process where they balance and interact with each other to form a meaningful whole for the individual pupil. The school should promote the harmonious development of pupils. This is to be achieved by means of a varied and balanced combination of content and working methods. Common experiences and the social and cultural world that make up the school provide scope as well as the preconditions for learning and development where different forms of knowledge make up the coherent whole’ (ibid, p. 6-7)

This text begins by explaining the content of knowledge: fact, understanding, abilities and familiarity. The first of these concepts is connected to traditional ways of looking at education and the last two concepts lean more towards knowledge through experience (Molander, 1996). The last part of this text quote contains ‘a whole’ that can be seen as integration. Teachers are expected to integrate knowledge. ‘Teachers should endeavour to balance and integrate knowledge in its various forms’ (ibid, p. 9). The section that deals with the head of the school expands the duties of the school leader to include facilitation of integration at the school level. This section also gives directions as to what themes are advisable to study in schools.

‘…teaching in different subject areas is co-ordinated so that the pupils are provided with the opportunity of broadening their overall understanding of wider fields of knowledge. […] interdisciplinary areas of knowledge are integrated in the teaching of different subjects. Such areas cover, for example, the environment, traffic, equality, consumer issues, sex and human relationships as well as the risks posed by tobacco, alcohol, and other drugs.’ (ibid, p. 18)

The National Agency of Education has written a text with commentaries to the curriculum, syllabi and grade criteria. In chapter 6 of this document, the content and organisation are discussed (Skolverket, 1996).

‘The argument to organise and choose content in one way or another must be based on professional considerations and local conditions. […] Even if the goals and the quantities of the students’ knowledge to be assessed are written as subjects it does not necessarily mean that the education should be organised subject-wise or that the content should be structured in that way. On the contrary there’s a lot to be said for considering other forms of organisation if schoolwork is to be meaningful for the students’ (ibid, p. 20, my own translation).

This text promotes integration of the content in school. Even though the curriculum is divided into subjects, students should have the possibility of creating, organising and integrating knowledge:
'The schools’ assignment of knowledge involves on the one hand transmitting earlier generations’ knowledge and on the other creating conditions for the students to organise and integrate in a meaningful and useful way.' (ibid, p. 21)

Nevertheless, organisation by subject is not abandoned:

‘Goals on the reproductive side of knowledge assignments are in the present curriculum organised subject-wise and express the aim that different aspects and qualities of the students’ knowledge shall develop.’ (ibid, p. 21).

Science education received one syllabus in Science and one in each subject of Biology, Chemistry, and Physics. They all follow the same general structure. First there is a common text, followed by a description of the aim of the subject and its role in education. After this general goals for the subject are presented as well as the structure of the subject and goals that students should achieve in grades five and nine. The structure of the subjects follows a common structure with three themes: knowledge of nature and Man, scientific activity, and use of knowledge. The Chemistry and Physics syllabi follow this pattern. Biology has four dimensions: the ecosystem, biological diversity, the cell and living processes and humans. Goals in Biology are similar to those in the other Science subjects with the three themes of knowledge of nature and Man, scientific activity and use of knowledge. The structure of the Science subjects differs from the Social Sciences, which do not show the same level of integration.

1.4 Summary of theories regarding science education integration

The last part of section 1 is a summary of the theories regarding integrated curriculum, particularly as they deal with integrated Science. Since these theories constitute the background and purpose of this thesis, they will be summarised here. We begin with a discussion of integrated curriculum studies in Sweden. Following this, integrated curricula will be contrasted with other curricula (traditional, abstract, fragmented or otherwise opposed to integrated curricula). Finally, the research question posed in the third section of this thesis is introduced.

The curriculum in Sweden has not benefited from the discussion about integration and subject-specific education that began in the 1980’s when students and teachers demonstrated both for and against integration. Investigations of past curricula in Sweden by Ingelstam and Riis indicate that integration was an important ideological and political viewpoint (Ingelstam, 1985; Riis, 1985). Marklund highlights the dichotomy used in the international debate regarding integration versus traditional curricula (Marklund, 1983). The National Evaluation performed by Andersson provided some insightful views from a student perspective regarding what students learned and student attitudes towards integrated and subject-specific Science education in Sweden. There are still unanswered questions regarding the Swedish view of integrated Science education as compared to traditional or subject-specific Science education.

There are also a number of sub-discussions within the international community regarding integrated versus traditional Science education. One is the ‘how’ versus ‘what’ debate most clearly presented by Yager and Lutz (1994). The discussion here deals with general abilities versus different subjects’ domain specific needs as to what and how things should be learned. Another sub-discussion deals with STS: many authors have worked with this since the mid-1980’s (Aikenhead, 2003; Fensham, 1988a; Yager, 1996; Yager & Weld, 1999). The STS
movement is a way of integrating not only Science but also Science and Society into a whole that students will find more interesting than questions posed by Science alone.

Yet another sub-discussion regarding integrated Science deals with the usefulness of learned Science in the light of the abstractness of traditionally taught school Science, with its curriculum overload and its large amount of content that must be covered in a short amount of time. In this discussion, arguments are often put forward about the relevance of integrated Science education, which is said to provide useful knowledge to students who may have a negative attitude towards Science due to the distance between school Science and students’ everyday experiences. Osborne and Collins provide an overview of this from interviews with students divided into focus groups. The students were asked what they find interesting, uninteresting and important in Science (Osborne & Collins, 2001). The picture that students paint is that

‘the disparate nature of Biology, Physics and Chemistry [results in] a failure to see any commonality or unity between the subjects.’ (ibid p. 454).

This is interesting since the next thing students say is that

‘the forced unity of the subject disadvantaged them, especially when it was examined and assessed, as those that were able at one science e.g. physics, were penalized by weakness or lack of interest in another, e.g. biology.’ (ibid p. 454)

A study by Venville et al confirms that there appears to be two ways of working with Science education which appear incompatible but

‘…if conceptual understanding of traditional scientific content knowledge is valued, perhaps an integrated approach to curriculum is inappropriate. If knowledge is valued as a conceptual tool to be used by students to apply to real-world problems and tasks, then an integrated approach to curriculum may be appropriate.’ (Venville et al., 2003)

Another sub-discussion in the debate on integrated Science education has to do with fragmentation versus wholeness. Wholeness is a goal for the curriculum, and meaningfulness of learning is used as an argument to accomplish this. Nobody wants fragmentation: students don’t want it, teachers don’t want it and headmasters don’t want it. A common argument against subject division is that it creates fragmentation in the students’ school day which in turn causes fragmented learning of content. This fragmentation exists in time, space and content and it’s sometimes difficult to assess which aspect is most important in the debate.

Until now, this study has presented different international and Swedish views regarding integrated Science education. The research question in this thesis deals not only with integration versus subject-specific Science education but also with differences and similarities between integrated and subject-specific Science education as well as student results’ in these different forms of education. In the next section, we will present an overview of the research in this area.

2. Previous research on student results

This section presents studies dealing with student results in different settings. A study of teachers’ learning styles, their students’ results and different student learning styles from the 1980’s will be presented first. Next comes a brief description of the rationale behind
international student assessments and the expected outcome of assessing students learning with the OECD’s PISA assessment instrument. Finally, results from students in STS teaching environments are presented, since STS is a kind of integration of teaching and learning.

2.1 Studies of teaching styles and student results

Studies have been conducted on teaching styles and student results. Intervention studies are the most common type of study in this area. In intervention studies, one group of students is treated in a specific way, another group functions as the control group (usually this involves working in the ordinary way) and student results are measured and compared at the beginning and end of the intervention. Some larger projects have dealt with student results compared to teaching styles (see section 2.1.1). Some international studies constitute a part of the data used in this study (section 2.2). In section 2.3, a short description of some of the findings of STS intervention studies may be found.

2.1.1 Bennett’s study of Reading, Mathematics and English

Bennett compared the use of integrated and subject-specific Science with students’ results in grades three and four in Lancashire and Cumbria (Bennett, 1976). He compared progressive and traditional teaching styles and described twelve different teaching styles. The progressive teaching style had as its first criterion integrated subject matter and the traditional teaching style had as its first criterion separate subject matter. A cluster analysis of 468 fourth grade teachers resulted in twelve types of teacher styles. Three types included teachers who preferred integrated Science and eight types consisted of teachers who preferred subject-specific teaching. One type was mixed. With further analysis, these twelve types collapsed into three teaching styles: formal, informal and mixed. Integrated and subject-specific teaching could not be distinguished from formal and informal teaching styles.

Evaluating student results in Reading, Mathematics and English, Bennett made a comparison of different gains relative to the three teaching styles. Students in formal and mixed classes had better gains than predicted in Reading and students in informal classes has less gains than predicted. Students in formal classes had better gains than predicted in Mathematics while mixed and informal classes had less gain than predicted. Students in formal classes had better gains than predicted in English while students in mixed classes had gains as predicted and students in informal classes had less gain than predicted.

Bennett described the kind of students who benefited or experienced disadvantages from different teaching styles. Students with high and low achievement levels benefited from formal teaching. Work-related pupil interaction was higher in informal teaching for both groups. Teacher interaction was higher in formal teaching for all level of achievers.

Bennetts’ data was re-analysed by Aitkin et al. (Aitkin, Anderson, & Hinde, 1981). They found

‘three latent classes and no single continuum of teaching style. The formal-informal “dimension” does not adequately describe the “mixed” teachers, who are not intermediate between the other two styles on the disciplinary and testing items.’ (ibid, p. 428).

Aitkin’s et al. re-analysis of the data produced no evidence for the assertion of a correlation between teaching style and students’ test scores. Aitkins et al. found that students in formal classes showed gains as expected in Reading while students in mixed classes showed less gain than expected and students in informal classes had better gains than expected. Students in
mixed and formal classes had the same results in Mathematics as in Bennett’s study but students in informal classes showed better gains than expected in contradiction to Bennett’s results. Students in formal classes showed gains in the same way in both Bennett’s and Aitkin’s studies in English but differences appeared for students in mixed and informal classes. These results, although statistically insignificant, were nevertheless different from Bennett’s. Aitkin writes that

‘the formal classrooms do best in English, the informal classrooms do best in Reading, formal and informal classes are very similar in Mathematics and the mixed classrooms do worst in all tests’ (ibid p. 438).

He concludes that

‘individual variations in teacher ability are much more important for pupil achievement than teaching style differences’ (ibid p. 439).

### 2.1.2 Swedish studies

The Swedish National Evaluation analysed teacher priorities, classroom situations and conditions in the light of teachers’ and students’ attitudes. A second analysis of the data collection was performed by the National Agency of Education (Skolverket, 2006a). The report concludes that teachers’ educational backgrounds (both in education and the subject taught) together with teacher enthusiasm are important factors influencing student results. Student results according to teaching style has been analysed in three core subjects: Swedish, Mathematics and English. The report discusses different cultures in the different subjects as a probable explanation for differences between subjects.

In the five-year project on no set timetable, there is a focus on the proportion of schools who work with integrated subjects (SOU 2004:35, 2004, p. 80) A growing number of schools participating in this project reported that they intend to start or have started integrated teaching. Students at schools participating in this project have shown better test results than students in other schools (SOU 2005:101, 2005, p. 146). A possible explanation for this is that more freedom to apportion time and resources leads to better priorities and better student results.

### 2.2 International studies

Two large-scale international student assessments are repeated every few years. The first has been going on for the last three decades\(^6\) (about once a decade) and the second large-scale international assessment started in the late 1990’s and constitutes a more frequent measurement of Scientific literacy\(^7\). There are similarities and differences between the two international studies. In this section, we will look at the rationale behind the two assessments. Section 4.3 will discuss differences in methods used in the two assessments. The focus for the PISA assessment differs from that of TIMSS\(^8\) and therefore PISA and TIMSS frameworks differ in some particulars. We begin with a presentation of the conceptual framework of TIMSS; its assessment levels are described in detail. Following this, the PISA framework will

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6 The IEA’s TIMSS assessment project
7 OECD’s PISA assessment
8 The Third International Mathematics and Science Study, which was renamed Trends in International Mathematics and Science Study when the fourth study was launched.
be dealt with from the perspective of intended student results and from an integrated perspective.

### 2.2.1 The rationale behind TIMSS

This thesis makes use of the TIMSS conceptual framework to analyse the qualitative case study (see section 6.1.2). Therefore a description of that framework is appropriate here. The conceptual framework for the TIMSS study consists of three levels: the *intended*, the *implemented* and the *attained* level (or curriculum as TIMSS calls it).

This framework is in turn based on the thoughts of Goodlad about the contextual frames for learning in a school classroom (Goodlad, 1979). The levels are not hierarchical in his model so there is no level that is above or stands without influences from the others. In Goodlad’s model the levels are interacting, and interaction can flow back and forth between each pair of levels connected with each other. The TIMSS framework has concentrated on three of the levels in Goodlad’s six levels model.

All three levels essential in the TIMSS model influence each other but the dynamics go from the intended to the implemented to the attained and not the other way around as opposed to Goodlad’s framework. The ideas behind the conceptual framework are as follows:

The variables influencing education are seen as situated in a series of embedded contexts starting from the outermost global context and moving towards the innermost personal context. The narrow contexts are influenced by the broader ones in which they are embedded, but they are not simply subsets of the broader contexts (Robitaille et al., 1993). Educational environments exist in a total environment that is larger than the world of education.

> ‘The boundaries between the content, the institutional arrangements, and the societal context are not always distinct. Nor is it important that they be clearly delineated. The important point is that the variables of three different kinds of content need to be considered in the light of three different levels of institutional arrangements, within three different societal contexts. Together, the content and institutional arrangements of the intended, implemented, and attained curricula, together with features of the society-at-large, the local community, and the educational environment.’ (ibid p.30)

The intended curriculum is Science defined at the national or school level. The intended curriculum is embedded in textbooks, curriculum guides, examinations, policies, regulations and other official documents designed to direct the educational system. It can be described in terms of concepts, processes and attitudes.

At the community level, the implemented curriculum is Science content presented by teachers to students. It can be described in terms of concepts, processes and attitudes. The focus of the implemented curriculum is the school or classroom. This includes teaching practices, aspects of classroom management, resource use, teacher attitudes and backgrounds.

The attained curriculum is the outcome of schooling, concepts, processes and attitudes towards Science that a student acquires in school. What students learn is influenced by what was intended and the quality and types of opportunities made available to them (both the intended and the implemented curriculum). It also depends on institutional arrangements such as the amount of homework, efforts by the student and student classroom behaviour patterns. The students’ personal background also influences the outcome of his/her studies.
Critical voices have been raised

‘that the “implemented” curriculum is determined, as much if not more, by the measurement of the “attained” curriculum – particularly when those measurements may be related to job security or performance-related pay.’ (Osborne & Collins, 2001).

In an international study like TIMSS, these factors influence students in all countries, although perhaps differently in different countries, and it is hard to discern this from the perspective of the international study.

2.2.2 Student results in PISA

Harlen discusses the PISA-study’s definition of scientific literacy (Harlen, 2001). This definition contains four aspects 1) Science processes 2) Science concepts 3) Areas of application 4) Situations within which assessment units are presented. There are five Science processes selected for inclusion in PISA: 1) Recognising scientifically investigable questions 2) Identifying evidence needed in a scientific investigation 3) Drawing or evaluating conclusions 4) Communicating valid conclusions 5) Demonstrating understanding of science concepts. Harlen discusses the rationale behind the PISA study. PISA aims not at defining each domain in terms of mastery of a school curriculum but at testing children for important knowledge and skills needed in adult life. The definition of scientific literacy in the PISA study is dependent on work done by Bybee (1997a). Bybee’s categorisation of a scientific literacy framework is a threshold model that assumes that the degree of scientific and technologic literacy is continuously distributed within the population. It recognises a continuum of scientific and technological literacy that can develop over a lifetime (ibid p. 55-56). The PISA study writes:

‘Scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity’ (OECD, 1999)

Knowledge and skills tested in PISA are called life-skills and are defined by PISA as

‘The knowledge, skills, competencies and other attributes embodied in individuals that are relevant to personal, social and economic well-being.’ (ibid, p. 11).

The PISA project devoted a good deal of effort to assessing active knowledge of reading and learning strategies, the ability to find answers in complex texts and the ability to judge and estimate different outcomes on the basis of given facts.

In PISA 2006, Science was the main area of assessment and the definition of the Science domain measured was extended compared to PISA 2000 and PISA 2003; in these earlier studies, the Science domain was smaller and Reading (in PISA 2000) and Mathematics (in PISA 2003) were the major domains. PISA 2006 measures competencies, knowledge and attitudes in the context of life situations that involve Science and Technology with emphasis on three competencies in scientific literacy called ‘Identifying Scientific Issues’, ‘Explaining Phenomena scientifically’ and ‘Using Scientific Evidence’ (OECD, 2007, p. 39). The competency ‘Identifying Scientific Issues’ involves recognising issues that are possible to investigate scientifically, identifying keywords when searching for scientific information and
recognising key features in a scientific investigation. The competency ‘**Explaining Phenomena Scientifically**’ involves applying knowledge of Science in a given situation, scientifically describing or interpreting phenomena, predicting changes, and identifying appropriate descriptions, explanations and predictions. The competency ‘**Using Scientific Evidence**’ involves interpreting scientific evidence, drawing and communicating conclusions, identifying assumptions, evidence and reasoning behind conclusions and reflecting on societal implications of scientific and technological developments. The domains assessed in PISA 2006 include physical systems, living systems, earth and space systems and technological systems; the three science competencies are intertwined with each of these domains. These competencies deal with Knowledge of Science and Knowledge about Science, to use PISA’s terminology.

### 2.2.3 The framework of PISA as it relates to integrated Science education

The results from the PISA study are analysed in two articles in this thesis. The framework of PISA 2006 provides many opportunities to assess concepts of Science, also integrated Science (OECD, 2006). Blum’s categories of intensity and scope are used to compare the PISA 2006 framework when it comes to integrated Science. PISA 2006 assesses student competencies in Scientific literacy. Those competencies are influenced by context, knowledge about the natural world (knowledge of Science) and knowledge about Science itself (knowledge about Science), as well as by student attitudes in these fields of interest, support for scientific inquiry and responsibility. Knowledge of Science is divided into four content domains; *Physical systems, Living systems, Earth and Space systems* and *Technology systems*. The knowledge about Science is two main areas; *Scientific enquiry* and *Scientific explanation*. The contexts are divided into five fields that can be applied to the personal, social or global domains. The five contexts are *Health, Natural Sources, Environment, Hazard* and *Frontiers of Science and Technology*. The PISA 2006 framework with knowledge of Science, knowledge about Science, competencies, content and the different contexts, are categorised according to Blum’s categories in this thesis, and the result is in Table 2.1.

As can be seen in Table 2.1 below, almost all of Blum’s categories are present when comparing PISA’s knowledge of Science, knowledge about Science, competencies and contexts with Blum’s intensities and scopes. The only exceptions are the categories ‘**Coordination**’ in the columns ‘Science and Society’ and ‘Science and the Humanities’. The competencies are placed in the *amalgamation* category, the knowledge in Science and the knowledge about Science are in the *coordination* and *combination* categories, and the contexts are spread in different scopes, with intensity of *amalgamation* and *combination*. While it’s possible to discuss the classification in these categories, superficially it appears that PISA’s aim of assessing lifelong-learning skills is met, assuming that lifelong-learning skills involve the ability to synthesise different domains in Science, Society and Environment into a single whole, instead of keeping things in separate boxes. When compared to previous analyses in Section 1.1.3, the PISA framework provides the most extensive description of integrated Science education according to Blum’s categories.

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9 Recommended reading for a deeper description of the content categories in the PISA framework is pp. 35-39 and pp. 44-46 in the International PISA report (OECD, 2007). The dimension of student attitudes is omitted from this analysis, since it is far from subject content and therefore incompatible with Blum’s categories.
Table 2.1. Analysis of the PISA 2006 Science framework according to Blum’s categories.

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Scope</th>
<th>Within subject</th>
<th>Between Science subjects</th>
<th>Basic / applied Science and Technology</th>
<th>Science and Society</th>
<th>Science and the Humanities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combination</td>
<td>Natural resources (global)</td>
<td>Hazard (social) Natural resources (personal) Earth and space systems</td>
<td>Natural resources (social) Frontiers of Science and Technology (social) Technology systems</td>
<td>Frontiers of Science and Technology (global)</td>
<td>Frontiers of Science and Technology (personal)</td>
<td></td>
</tr>
<tr>
<td>Coordination</td>
<td>Physical systems Living systems</td>
<td>Scientific enquiry Scientific explanations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The TIMSS framework does not readily fit into Blum’s categories, since the Science domains in TIMSS are more subject-specific and the Science cognition domain in TIMSS assesses more general skills. This is not surprising, since according to Fensham (2006),

‘the Science content knowledge emphasised in the TIMSS tests in the 1990s and the 2000s has continued to be academically-oriented rather than a wider ‘Science for all’ that takes account of the demands that Science and Technology in contemporary life place on students and citizens. TIMSS, in this way, has chosen to ignore the now considerably-expressed concern in many of its participating countries that interest in Science for careers or for lifelong-learning is waning alarmingly.’ (ibid. p.216)

The emphasis in TIMSS, according to Fensham, is on traditional subject-oriented content and not on integrated life-skills, since TIMSS’ aim is to assess participating countries’ curricula (ibid p. 217). This approach has its consequences:

‘That the same framework was unquestioningly seen to be appropriate for students’ learning of Science at the primary, lower secondary and senior secondary levels of schooling implies that in TIMSS it was assumed that the teaching/learning of Science has the same purpose at each of these levels.’ (ibid p. 219)
The picture of TIMSS as painted by Fensham shows a series of questions in different subjects that are fragmented and factual, questions that do not deal with students’ contextual situation or their everyday experiences. This occurs because the curriculum TIMSS measures is a traditional curriculum.

2.2.4 Comparing the frameworks of PISA and TIMSS

Differences between PISA and TIMSS may be found in Fensham and Harlen (1999). The main difference between the intentions of PISA and TIMSS is that the PISA study is not founded on different countries’ curricula but on

‘learning outcomes for Science that had not previously been emphasized and as a test it was unlike the types of testing that were familiar in the countries’ school systems.’

(Fensham, 2004).

A thorough analysis of the frameworks of PISA and TIMSS is found in Olsen (2005a). The frameworks are similar in that both measure knowledge and skills in Mathematics and Science. However, PISA also assesses reading literacy, a domain outside the purview of TIMSS. TIMSS and PISA differ in framework when it comes to national curricula: TIMSS is grounded in national curricula, while PISA does not explicitly measure national curricula but rather general competencies. Curriculum is thus central to TIMSS. TIMSS distinguishes between curricular intentions and outcomes, and analyses discrepancies between the two. In PISA, life skills are prioritised over school-defined skills. That PISA concentrates on life-skills is not surprising since PISA was initiated by the OECD, which works with work and efficiency related questions. One of a country’s main competitive elements is its general level of knowledge (Gustavsson, 2000). The relative importance of curricula in TIMSS but not in PISA affects the choice of instruments in both tests and there are important differences in the two tests’ choice of instruments.

One indication of differences in results between PISA and TIMSS is that, according to PISA, girls score as well as boys in Science at the international level (Fensham, 2005). There has been a discussion about this result in the light of PISA’s emphasis on language literacy; a case has been made that, since PISA items require a high level of literacy and since girls in general score higher on literacy skills than boys, this may explain girls’ parity with boys in Science. In the TIMSS study in Sweden, boys showed better results than girls in Science (Skolverket, 2004). One suggested explanation for this difference is that girls in Sweden favour an open question format, which TIMSS established in its question format surveys in Sweden (Eriksson, 2005). TIMSS has a lower rate of open questions than PISA, so it is possible that an explanation for the lack of differences between girls and boys results in earlier PISA studies is the question format.

2.3 STS intervention studies

A group in the USA led by Robert Yager has worked extensively with STS intervention studies. Several doctoral theses have been produced which investigate student results, differences between groups, etc. One example of the work produced in this field may be found in Mackinu (1991). In this study, five domains were investigated: Science concepts; Science process skills; Science concepts and principles; creativity; and attitudes. When students’ grasp of scientific concepts was measured, no significant differences could be established between classes with textbooks and those using the STS approach. When it came to other categories (Science process skills, application of Science concepts and principles, creativity, attitude towards Science), classes taught with STS methodology scored
significantly higher than comparable textbook classes. There were no differences between girls and boys in the five domains, with the sole exception that girls displayed a more positive attitude towards Science in STS classes. Growth in these five domains was also investigated and students in the STS group displayed greater growth (ibid p. 109-113).

Bennett performed a meta-study of context-based and STS approaches (Bennett, Lubben, & Hogarth, 2006). The quality of 24 experimental studies and 37 non-experimental studies were examined. Quality criteria established 16 studies of high quality and these were investigated more deeply. The studies were assessed on the basis of outcomes (understanding, attitudes, gender and abilities), overall quality and nature of interventions. When it came to the size of interventions’ effects, one study received a rating of 1.52, a very high score for educational interventions. Investigating understanding of Science as an outcome, context-based and STS approaches to education proved to be at least as effective as conventional approaches according to the four studies that had studied this. When it came to attitudes towards Science, seven out of nine studies indicated that context-based STS approaches improved students’ attitudes as much as conventional methods. Three out of five studies showed that gender differences were reduced with context-based approaches. One study investigated differences in student ability; in this case the context-based/STS approach resulted in better conceptual understanding of Science and more positive attitudes towards Science among low achievers than similar students in conventional classes.

3. The research question in this study

To begin with, Science education in Swedish schools will be presented to establish a context for this study. In the second part of this section, the study itself will be presented. Finally, the research questions that have guided this study in all its parts will be presented.

3.1 The structure of Sweden’s Science education compared to Science education in other countries

At present, the curriculum for Swedish compulsory schools grants schools autonomy in planning Science teaching, organised as integrated or subject-specific teaching (Skolverket, 2001). Sweden has a long tradition of Science teaching in the compulsory school system. Science and Social Science are usually integrated during the first school years and these subjects are taught by the same teacher or a team of teachers (Henriksson, Gisselberg, Karp, Lyxell, & Wedman, 1987). In the seventh grade children usually meet Science in separate subjects (Biology, Chemistry and Physics). Divided and specialised, the contents of these subjects are a miniature of the academic disciplines. The amount of Science in compulsory schools is at least 12 percent of guaranteed teaching time at school. If Mathematics is added to the Sciences, as is often the case in Swedish educational discussions, total guaranteed teaching time rises to at least 25 percent. A minimum of 12 percent guaranteed teaching time in the Sciences is less than the amount specified in other countries, where the proportion discussed is closer to 15-20 percent of school time (Hurd, 1986; Shamos, 1995; Whitfield, 1980).

The issues of how to establish Science in the schools and what its role should be, issues that are commonly discussed in international debates, is noticeable by its absence in official discussions in Sweden. Fensham (1985) discusses the problem for Science education, which must both educate students for Science careers and for personal and social needs in a context of life-long learning. This approach to Science education is practiced in Sweden, since Science education is compulsory through lower secondary school. Fensham (1985) suggests
that one of the problems of the dual goals of Science education is that students are reluctant to choose Science due to lack of interest and lack of preparation. In Fensham’s opinion, all students need Science but not necessarily in the form of preparation for higher academic studies, a form of Science education that is very common from an all too early age in many countries (Fensham, 1985). Hurd (1986) has pointed out that this particular problem with Science education has been an ongoing discussion during the entire 20th century. His own suggestion for resolving the problem is to gather the stakeholders in Science education to a discussion about what really matters in Science education (Hurd, 1986).

Fensham (1985) suggests that one way to prevent students from losing interest in Science is with a strategy of containment. This means that Science for higher academic studies is not offered below a certain level in the educational system. Containment strategy is adapted for two streams: those who intend to study Science at a higher academic level and those who do not. Students who do not intend to continue with Science still need to be prepared for life-long learning in Science as the need arises.

In this thesis, the example in Fensham (1985) that has been adapted to Swedish circumstances originates from Thailand. In 1994, Sweden adopted a similar model for compulsory and upper secondary schools. Two things distinguish the Swedish from the Thai model. First of all, lower secondary schools, with Science for all, maintain course plans in Biology, Chemistry and Physics or the natural sciences. Secondly, teachers in Sweden can give students grades in Science or Biology, Chemistry and Physics. Students receive in other words one or three Science grades for the same amount of course time (SOU2007:28, 2007). Regardless of whether they receive one grade or three, the objective in lower secondary school is the same: by the end of the 9th grade, students should have studied the same amount of Mathematics and Science and should have attained the standards set for these subjects. The most common way of organising Science education is to work with general Science in the first six grades: Biology, Chemistry and Physics appear jointly in thematic studies, or, alternatively, they appear sequentially. In the last three grades of compulsory school, the sciences are most commonly differentiated into separate courses in Biology, Chemistry and Physics; less often they remain together in the general subject Science.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Lower secondary school</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>(All pupils) General Science Biology, Chemistry, Physics</td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>(All pupils) General Science</td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Figur 3.1.** A model of Science education in compulsory Swedish school system.
3.2 A Science education research question

Whether the goal of Science education is preparation for secondary school and academia or if it is universal scientific literacy, was one of the most discussed questions in Science education during the 1980’s and 1990’s. This has been thoroughly discussed in the Science education society of Great Britain (Jenkins, 1999), Australia (Fensham, 2000; Fensham & Harlen, 1999) and Canada (Aikenhead, 1996). What should good Science education result in and how does one achieve these results?

The school debate in Sweden has dealt with efficient use of school time, (Westlund, 1998) and integration and individualisation (SOU 2004:35, 2004). Sweden has launched two curricula reforms in recent times (1994 and 2000). Teachers have experienced major cutbacks in work time, when responsibility for schools shifted from the state to municipalities in 1989. All these factors have influenced the discussion of school Science, although none of them have directly impacted on the content of Science education.

The following research questions are posed: How does one define integrated Science education and how does one put it to a test? The aims of this thesis is to explore and to test

- What are the similarities and differences between integrated Science and subject-specific Science education found in literature, by experts and in cases?
- What (if any) differences in Scientific literacy results tested with PISA data 2003 and 2006 for Swedish curriculum in the lower secondary school stem from the fact that some students received integrated Science and others subject-specific Science education?

Delimitations regard, as mentioned in the above sections, the boundaries between integrated versus subject-specific Science arrangements, which are not clearly defined, nor are the two arrangements in themselves a singular phenomenon. In this thesis, teachers’ views on how they work with and interpret Science education is taken as data and analysed according to established statistical and qualitative methods. In accordance with Andersson’s 1992 study, teachers who express that they work thematically are categorised as belonging to an integrated Science arrangement and those who state that they teach Biology, Chemistry and Physics as separate subjects, are categorised as belonging to a subject-specific Science education.

The thesis will explore integrated and subject-specific Science education both theoretically and experimentally. The thesis consists of four studies. One study concerns the structure and content of integrated and subject-specific Science education from the point of view of experts in Science education. Another study concerns the way teachers view integrated and subject-specific Science education. Two studies concern student results in PISA 2003 and PISA 2006, grouped into students with integrated or subject-specific Science education.

4. Methodological considerations

In a section like this, methodology, ontology and epistemology are often discussed. The character of the collected data is often mentioned and methods of data collection and analysis are described. A meta-level of discussion can occur, where a project or the ideas about a project are described and analysed as part of a methodological discussion, see for instance (Olsen, 2005a).
This section will treat the world view which functions as a backdrop for this empirical study of Science education. The ontological aspect will be addressed: given our present knowledge and methods, what can be investigated? This section will also describe how analysis took place; a common way of analysing quantitative data is through hypothesis testing and one part of this section will deal with how this was done and what prerequisites are necessary for hypothesis testing. Finally, the methodology section introduces the international student assessment paradigm and how it is dealt with in this study.

The analysis differed depending on the data collected and there are two sections dealing with the quantitative and qualitative nature of the data. This part addresses the bigger context of the four studies in this thesis. Detailed presentations of the methods used in each study are found within the respective paper. A discussion of the quantitative study is followed by a discussion of the qualitative study. Ethical aspects of the research are also mentioned.

4. 1 Ontological framework

There truly appears to be something called integration which is both discussed and implemented. Integration appears as an ideological issue in politics, administration and in practice in the Science classroom. Integration is ideologically opposed to other concepts, such as separation, fragmentation, alienation and isolation. Integrated Science education is, however, not a sharply defined and well demarcated subject that everyone can agree on. That integration actually exists is the first postulate of this research thesis and without this postulate this study would be meaningless. It also becomes clear when reading the literature dealing with teaching and education that integration is an ideologically important issue. It is therefore appropriate that this thesis contributes to the discussion by presenting facts regarding the situation in Sweden as it pertains to integration in order to learn what the fuss is all about.

The view that there is something worth investigating and that it is an important question to investigate, is the starting point of this research. This starting point differs from doctoral theses where departmental methodology defines the research. It also differs from the common research framework that positions the thesis as a part of a bigger research project; in these cases, data is collected by the larger research project and this data defines any possible research. Since this thesis was written for the department that administers and analyses PISA results, a simple way of performing research would be to work with data collected by PISA to find something interesting for research. This avenue was investigated and it was soon discovered that, although PISA results represent a valid and reliable database, they cannot provide answers to one of the most hotly debated educational issues in Sweden: the role of integrated and subject-specific education. The scope of this research was therefore widened to include a classic question in the field of Science education that has attracted research since the 1930’s. Many useful things were learned while researching this area, not least of which was that there remain things to find out regarding this question.

To place the nature of this research into a context, it will be helpful to explore the epistemology of realist research. According to Robson a realist view of Science contains the following components:

1. There is no unquestionable foundation for science, no ‘facts’ that are beyond dispute. Knowledge is a social and historical product. ‘Facts’ are theory laden. 2. The task of science is to invent theories to explain the real world, and to test these theories by rational criteria. 3. Explanation is concerned with how mechanisms produce events.
The guiding metaphors are of structures and mechanisms in reality rather than phenomena and events. 4. A law is the characteristic pattern of activity or tendency of a mechanism. Laws are statements about the things that are ‘really’ happening, the ongoing ways of acting of independently existing things, which may not be expressed at the levels of events. 5. The real world is not only very complex but also stratified into different layers. Social reality incorporates individual, group and institutional, and societal levels. 6. The conception of causation is one in which entities act as a function of their basic structure. 7. Explanation is showing how some event has occurred in a particular case. Events are to be explained even when they cannot be predicted.’ (Robson, 2002).

Figure 4.1, presented in Robson, (ibid p. 31) portrays a realist explanation of research.

![Diagram of realist explanation of research]

**Figure 4.1** The realist explanation of research

Figure 4.1 shows an action done to someone or something within a context. The researcher wishes to explore a particular mechanism that acts on the research subject and does this by studying the outcome. The outcome is dependent on the mechanism and context. This is the case for the situation studied in this thesis. By investigating outcomes (assessment results), mechanisms may be compared (integrated and subject-specific Science education) to determine which mechanism produces the most desirable outcomes. The action is the same for all students: they go to school and learn things. This action is of course very different in different circumstances. What students learn, how they learn and their results in the form of achievement and attitudes towards school, learning and study are all dependent on various factors, such as social background, gender, ethnicity etc. Contexts may vary since Science classrooms differ from school to school, teachers work differently and textbooks differ. One element of the Science classroom in Sweden is however invariable: they all share the same national Science curriculum. Implementation of the curriculum may vary, but the curriculum is mainly the same.
4.2 Different results for an individual

Any large scale quantitative study that makes use of statistical analytical methods must account for several particulars. The validity of the variables needs to be carefully considered to answer the question: are the correct things being measured? Two issues must be addressed in this section: the issue of repeated measurements and the issue of interference with results due to student pre-knowledge.

A problem with any study like this is that only one measurement for each individual is made at a single specific point in time. In order to learn more about student development, at least two measurements should be made. This has been disputed by authorities in statistics, for instance Goldstein (Goldstein, 2004). Regardless of this, the sampling process used in PISA precludes the possibility of making more than one measurement.

A second issue when doing a study like this is the possibility that other factors may influence the results, factors which are impossible to take into account given the methods used or the variables collected in the data set. One such factor is called Aptitude Treatment Interaction (ATI\textsuperscript{10}).

‘When ATIs are present, a general statement about a treatment effect is misleading because the effect will come or go depending on the kind of person treated. When ATI is present, a generalization about aptitude is an uncertain basis for prediction because the regression slope will depend on the treatment chosen.’ (Cronbach, 1975, p. 119).

Aptitude Treatment Interaction is defined as follows: Aptitude is

‘any measurable person characteristic hypothesized to be propaedeutic to successful goal achievement in the treatment(s) studied; propaedeutic means needed as preparation for response to treatment. In other words, individuals differ in their readiness to profit from a particular treatment at a particular time. [...] An aptitude, then, is a complex of personal characteristics identified before and during treatment that accounts for a person’s end state after a particular treatment.’ (Snow, 1991, p. 205)

‘An aptitude is thus a relational construct, interpreting the behaviour of person-in-situation, and characteristics of the situation are as much a part of the definition of a particular aptitude construct as are characteristics of the person. [...] ATI is said to be present when in some group of persons an aptitude variable shows a different relation to an outcome variable in one treatment than it does in another.’ (ibid p.206).

Three different outcomes of an aptitude interaction treatment are described in Gustafsson (1976, pp. 192-193). The first is that students of lower ability have better outcomes than expected from the treatment when compared to students of higher ability (disordinal interaction). The second is that students of higher ability have better outcomes than expected from the treatment when compared to students of lower ability (ordinal interaction). The third is that the treatment does not influence the outcome for any of the groups. In a large scale study like PISA, it is impossible to find other variables than the ones collected. We can therefore only establish correlation or lack of correlation between the variables collected in the sample. It remains possible to perform data mining with the variables to determine the

\textsuperscript{10} ATI stands for Aptitude-Treatment Interaction
probable existence of variables that may relate to some of the groups or teaching organisations. However, this data mining can never provide clues to the existence of variables influencing the results that are totally outside of the variables collected in the data.

Returning to investigations of student performance and differences in outcomes, Cronbach and Webb reanalysed a study by Anderson from 1941 and compared two styles of instruction in Arithmetic. The Anderson study is considered a classic. Anderson’s study showed that the drill method was a superior method for ‘overachievers’, i.e. students with good past achievement but relatively poor scores on tests of general ability. ‘Underachievers,’ on the other hand, tended to do better with instruction that emphasises the meaning behind processes rather than drills (Cronbach & Webb, 1975). Cronbach’s conclusion is that investigators can collect data on intact classes and then separately examine regressions between and within groups.

4.3 Regarding international student assessments

Data used in two of the studies in this thesis comes from one large-scale international student assessment; therefore it is appropriate to mention the methods used in this kind of project. Volumes have been written on technical aspects of the assessment, see for instance the technical reports of PISA (OECD, 2002, 2005b). Digital data analysis manuals available for download are available to researchers who wish to interpret the international student data files (OECD, 2005a). The framework used to plan and administer the assessments is psychometrical, i.e. the methods are garnered from books dealing with those questions, see for instance Crocker & Algina (1986). Many of the ideas behind international student assessment come from psychology as well as from educational research on subject relevance in measurements. International student assessments provide information about several things. As an example, TIMSS provides comprehensive information about concepts in Mathematics and Science, processes and student attitudes. There is also information about overall achievement in Mathematics and Science and in major content areas; these permit informed international comparisons of student achievement over time. It is possible to find strengths and weaknesses in student learning both within a country and compared to other countries. It is also possible to learn more about performance in population subgroups within a single country. This information may help researchers discover the presence of unequal opportunities for minorities in a country Howie & Plomp (2006).

Different international student assessments do not share a single scope or aim, although they display some similarities. Two international student assessments which seem to measure the same thing - IEA’s TIMSS and OECD’s PISA - are presented here. The operative word here is ‘seem’; both assessments certainly measure Science and Mathematics. However, there are important similarities and differences between the assessment frameworks, as previously discussed in section 2.2.4. The two assessments also use different methods. A thorough description of similarities and differences in population, samples, design and instruments may be found in Olsen (2005a, p.31).

Similarities between the two assessments when it comes to population and samples include the fact that in both cases the populations are large, quality is high, there are strict procedures for exclusion and well-defined minimum criteria for participation rates. As for design of the instruments, similarities between the two assessments include the fact that both are paper and pencil tests (although PISA will attempt an advanced format of computer assessment in PISA 2009), both present a combination of multiple choice questions and open answer questions, both contain student and school questionnaires, both are measured in a cyclic manner to
assess trends, both use a rotated design in the student booklets and both have strict procedures to ensure quality.

Differences between the two assessments when it comes to population and samples include the fact that PISA concentrated on one population (15-year-olds) and samples were school based, while TIMSS studied different populations during different cycles and samples were class based. As for design, differences between the two assessments include the fact that items are more ‘school-like’ in TIMSS while in PISA they are organised in clusters with a common stimulus introduction. TIMSS includes an obligatory teacher questionnaire which in PISA is optional (since the focus in PISA is not on school issues but predominantly life-long learning issues). In TIMSS, every country uses the same instrument while in PISA individual countries may opt out of some of the instruments. There are differences between TIMSS and PISA when it comes to reporting; in TIMSS the major focus is on class analysis while PISA works at the national level with a focus on school context, socio-economic factors and learning strategies.

To discover more about the validity of measured constructs in international assessments, it is useful to investigate the assessments’ alignment with national curricula. In 2003, comparisons of three large-scale assessments (NU, PISA and TIMSS) in Sweden showed that, of all three assessments, PISA most closely adhered to the national Science curricula (Skolverket, 2006b). Almost all Science questions in PISA were context based, either by situation or by question or both. However, the proportion of questions in each of the three sciences (Biology, Chemistry and Physics) was somewhat unbalanced since most questions dealt with Biology. PISA deals with knowledge of specific facts and general abilities in about the same proportions (57 percent facts and 43 percent general abilities). The proportion among the three Swedish curriculum goals (Nature and Man, scientific activity and use of knowledge) is well balanced in PISA (nature and Man 31 percent, scientific activity 20 percent and use of knowledge 31 percent). The difficulty level of the items was somewhat larger in PISA than in the other two assessments (NU and TIMSS). This analysis was made during a year when Science was not the main domain for the PISA study; nevertheless, PISA displayed good alignment with the Swedish curriculum.

5. Methods of data analysis

Statistical techniques are used in this thesis to analyse results. Before using these techniques, the statistical methods themselves must be studied. Qualitative data, interviews and surveys have been used and analysed in a qualitative way. One part of this section is dedicated to that method. Finally, research ethics are discussed.

5.1 Analysis of quantitative data

Three studies presented in this thesis make use of quantitative data. The population of two studies consists of fifteen year-old students in the 9th grade in Sweden who took the Science section of PISA in 2003 and in the PISA 2006 assessment. One quantitative study consists of data from a highly selective population of experts and teachers in Science education in Sweden. One of the studies uses hierarchical linear modelling (Tabachnick & Fidell, 2007) to statistically analyse results for fifteen year-old students in the 9th grade, with variables of country of birth, home language, preschool attendance and an index of economic, social and cultural factors entered as covariates of school teaching organisation. These variables were chosen to allow comparisons with PISA 2003, Mathematics (OECD, 2004) but also because

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they commonly have the largest impact on student results. PISA displays different results for Mathematics and Science but since the chosen independent variables explain much of the variation, it is interesting to look at the extent of variation. Hypothesis testing of mean results for different groups of fifteen-year old 9th graders is used as an analytical method in the other study. The third study, the Delphi study, also uses statistics for analysis. In the following section, statistical testing will be discussed, particularly hypothesis testing as an analytical method.

5.1.1 Hypothesis testing

In statistics, one basic method of analysing data is to compare groups to see if samples representing different groups have different characteristics or if they represent different populations. This analysis is most simply performed by comparing group means. The question is: when comparing groups, what is the probability that observed differences are real differences and not random occurrences?

To make comparisons, one must either have groups that are treated differently or two distinct groups that differ in a way that could affect the outcome or dependent variable. Comparison of means involves hypothesis testing. The null hypothesis is that no differences exist between the groups. The hypothesis tested is to find observed differences in group means. This form of hypothesis testing can only take place under certain conditions: the sample needs to be random and representative for the population studied. If the sample is not representative of the population, conclusions drawn from hypothesis testing may not be applied to the general population.

When hypothesis testing, desired results include acceptance or rejection of the null hypothesis. Both results are deemed desirable since they establish a truth. However, testing of mean values involves an error term and false results can occur in two cases, which in hypothesis testing are termed Type I and Type II errors. A Type I error involves rejecting a correct null hypothesis. A Type II error involves accepting an incorrect null hypothesis.

Recommendations regarding sample size, significance level and measured mean values should be kept in mind when doing this analysis. If the significance level is reduced, the chance of accepting a false null hypothesis increases. If sample size increases, the chance of accepting a false null hypothesis decreases. The risk of accepting a false null hypothesis is inversely related to the size of the difference between the hypothetical and mean values, i.e. the greater the difference, the lower the risk of accepting a false null hypothesis. The strength of a test is measured in terms of the probability of rejection of a false hypothesis. The more strength a test has, the better it is.

The other issue to consider is whether or not the variables studied have some effect on the dependent variable(s). Therefore the effect size of the variables used in the calculated model is often calculated to see if the influence of the variable is of interest (Cohen, 1990). Calculation of the effect size is however not a straightforward task, since there are many ways of calculation that entity, depending on the model and the variables. The calculations in paper 3 show some example on this issue.

5.1.2 Validity

There are some considerations concerning validity when using assessment instruments like PISA. According to Linn and Gronlund the following five things are considerations that need to be taken into account when reasoning about validity: Validity refers to the appropriateness of the interpretation of the results of an assessment procedure for a given group of individuals.
Validity is a matter of degree. Validity is always specific to some particular use or interpretation. Validity is a unitary concept. Validity involves an overall evaluative judgement (Linn & Gronlund, 2000, p. 75-76). Linn and Gronlund also write about four considerations of validity in assessment that are all related, but can be taken into consideration to different degrees depending on what kind of assessment is at stake. The four considerations are; content, construct, assessment-criterion relationship and consequences for teachers and students.

The quantitative design of the two studies that uses PISA data allows us to find the frequency of schools and students having integrated and subject-specific teaching. It also gives us the opportunity to correlate students’ results with different organisations of teaching and study, to see if there are differences between students’ results that are related to the organisation of teaching. The methods used are statistical, and hypothesis testing is performed with statistical interference. It is used to test the hypothesis, in this case to find if there are differences between two ways of organising Science education. The statistics help us answer the question of possible differences between different groups, and whether this difference is statistically significant. The statistical strength of the test is a measurement of the ability of the statistical test to examine a difference between the null-hypothesis and the hypothesis that there are differences between groups or categories. The model used is an abstraction to describe the data. The metric level of the variables measured is a crucial issue for the kind of model that can be used to test the hypothesis (Henriksson, 1999).

In this study, statistics are used to test the hypothesis that there is a difference between groups of students taught using integrated Science education and groups of students taught subject-specifically in Biology, Chemistry and Physics. A first question of the validity of the assessment instrument would lead to a discussion too long for this thesis, and will not be developed in its entirety at present, but a lively debate about the advantages and disadvantages of an assessment tool like PISA is present in the research community. One advantage that can be observed is the reports written about the results that give us more knowledge about the school systems in different countries (OECD, 2001, 2004). Interesting results regarding gender differences have been found (Fensham, 2005). The disadvantages of large-scale assessments are discussed, mainly at a systems level and concerns are expressed about assessment effects. Sjöberg (2002, 2005a, 2005b) is concerned about the top-down view. Prais wonders about the aims of PISA (Prais, 2003). Criticism related to students’ ability to learn is noted by Goldstein (2004).

Another, second question concerning the validity of the statistical method used may be easier to discuss briefly. The sampling of the PISA assessment mainly determines what kind of analysis method is useful. Since the sample is nested at two levels and designed with students at one level and schools at the other (OECD, 2005b), a hierarchical linear model is an appropriate way of analysing differences between sample means (Tabachnick & Fidell, 2007). The hierarchical linear model is able to separate the calculation of variance at the individual level from variance at the school level. This is necessary, since one presumption is that students in a class with the same teacher are not independent in the statistical analysis.

In summarising the different parts of the validity discussion, the process used with the assessment instrument and the statistical methods are found to be satisfactory. One remaining issue when discussing validity in the quantitative study is the variable of teaching organisation.
5.1.3 Reliability
Reliability is concerned with the consistency of measurements. Is it possible to reproduce the results with the same data, and is it possible to reproduce data and get the same results?

The measurement procedure of PISA is well documented in data analysis manuals (OECD, 2002, 2005b). The reliability of the assessment instrument is guaranteed by the assessment procedure. The students’ results are assessed by comparative judges in multiple rounds. Inter-judgement reliability is measured and reported. The concerns about PISA are about whether the content of the items measure what was intended. Bonnet (2002) expresses concern regarding the reliability of some test items: the amount of skills it intended to measure are not the same as the skills reported, which raises the question of the need for an independent comparison.

The variable of school organisation collected in the survey of autumn 2003 is a more empirically untested factor in the study and therefore more uncertain than the others. This is due to the fact that there are difficulties in knowing what the labels different types of organisation use really describe. The agreement between the schools’ answers to the survey in autumn 2003 and student grades in Science is not completely coherent, as is discussed in section 6.2.1. However, in the second study with PISA 2006 data, the variable school organisation is collected in the school questionnaire, and the relative proportions between integrated and subject-specific Science are similar to those found in autumn 2003. Therefore the number of schools with integrated and subject-specific Science seem to be invariable between different years and samples. The uncertainty that is found in the variable of integrated and subject-specific Science organisation may mainly be associated with the socially negotiated facts in the schools with integrated and subject-specialised organisation of Science education. Socially negotiated facts can have different meaning and content for different users and at different times. A discussion of socially negotiated facts is found in Searle (1995).

5.1.4 Generalisation
The study samples are chosen randomly from a representative population in Sweden and they could be generalised to the entire population of fifteen-year old 9th graders. Missing data is equal in different strata groups, so no student group is missing. The sample is representative for the population. For more details about missing data in the study, see papers 3 and 4.

5.2 Analysis of qualitative data
Only one study in this thesis is of a purely qualitative nature: a study of four schools in a town in Sweden. However, even here there are elements of qualitative data collection and analyses of some of the parts of the quantitative studies. This is described in the first section below. The following sections discuss validity, reliability and generalisation of the qualitative data analysis.

5.2.1 Case study method
The case study in this thesis is a qualitative multi-case study combined with a small amount of survey data. However, according to Robson, a pilot study may also be reckoned as a case study (Robson, 2002, p. 185). Robson refers to Yin (1994) where Yin distinguishes between pilot tests and pre-tests. Pilot tests help the researcher refine data collection plans in relation to both content and procedures. According to Yin, pre-tests implement the intended data collection plan as faithfully as possible. Using this definition of qualitative case studies, this
thesis consists of several qualitative case studies. Questions about thematic and subject-specific education as they appear in studies 3 and 4 are pilot studies: a number of teachers answered the questions and the researcher refined the questions after discussing them with these teachers. Another example of a qualitative study is the case study of four schools in a town: this study helped clarify how integrated and subject-specific Science in Swedish works in practice; and development and pre-testing of the survey for the Delphi study.

Note that Yin distinguishes between pilot cases and pre-tests: pilot tests help form the main study by assisting the researcher in developing questions, whereas pre-tests also test the process of conducting the study. According to Robson, a case study must contain the following elements: it must have a strategy, be concerned with research, be empirical, be about the particular, be about a phenomenon in context, and use multiple data collection methods (Robson, 2002). Any case study must also answer a number of questions before it can begin, such as: Which cases should be selected? Will the study consist of a single holistic case or multiple cases? What is the focus of the study? The case study of four schools in a town is a study of multiple cases. Each school represents one case and the teachers at the different schools are imbedded cases in the schools (Yin, 1994). Factors of a practical nature also influenced the choice of cases. These factors included narrowing down the schools to a particular set of cases within a convenient geographical distance from the researcher; by selecting nearby schools, it was possible to be present at the school at different times when collecting data.

The case analysis of the four schools study is both qualitative and quantitative. Analysis of interviews focuses on themes and concentration of meaning (Kvale, 1997). The themes from the interviews are described and compared to the literature on Science education, especially regarding integrated curriculum and integrated Science. The analysis of the school survey is a simple comparison of school survey results with teacher interview results. The student survey is analysed with non-parametric statistical methods (Henriksson, 1999; Welkowitz, Ewen, & Cohen, 2000).

### 5.2.2 Experts’ study

The methodology used in the experts’ study needs to be considered. When preparing the survey, one way of discovering what teachers and curriculum experts think about integrated and subject-specific Science is to ask them. In this study, however, the technique used to gather data was surveys with questions developed from different theoretical sources for experts to evaluate in an independent manner.

It is quite difficult to get ten different opinions in a group of ten persons discussing issues. More often there are some people with high status in the group that ‘set the tone’ for making proper statements, and many other people in the group are quiet, or express their opinion on a particular issue only briefly (Murry jr & Hammons, 1995). Therefore, the method used did not involve meetings with all the informants gathered to discuss the statements. The independent manner was an idea based on experience of group discussions in person by people, both teachers and others.

Gathering viewpoints from informants on a subject with many possibilities to make one’s own interpretations of concepts involves methodological problems; success depends on taking several things into consideration. First of all, the issue must be of interest to the person whose opinion is being asked. The person should have reflected about the issue and developed opinions of his or her own founded on practical experience. Secondly, it is important to ask
the right people. They should have experience in the field. Thirdly, the questions asked must reach the core of the issue, both from the perspective of the researcher and the person asked. Fourthly, the people asked should not influence each other; the expert study was helpful in this regard, since participants never met or discussed the questions.

One issue that has been considered intensely when conducting the expert study is the validity problem; were the questions the proper ones to ask? The solution to the validity problem was to ask questions related to theory that describes integrated Science education, and the brief descriptions found of subject-specific Science. A second solution to the validity problem was to pilot the survey with persons having approximately the same background as the informants. The standpoints and attitudes that emerged from the pilot were thoroughly woven into the survey to enhance validity.

The four domains in the survey: work forms, content, reason for integration and the target group (of a specific way of teaching), are all found in the literature as important domains in the area of integrated curriculum. The domain of reasons for integration and target groups for integration seems to have a lot more emphasis in the literature. The work forms and content were less written about. However, in a science educational research study the work forms and content would have the main focus, so it was of outmost importance that those areas were represented in the survey. When constructing statements that would suit each domain, it was not easy to strike a balance between the different domains. For instance, the questions dealing with work forms seemed to have puzzled informants, since some comments to the survey dealt with these questions.

In the present expert study, there is a poor response rate. The study is quite small; only 24 experts were given the survey. Only 18 sent the survey back. Poor response rates make statistical methods difficult to use and influence data processing and outcomes. If, for instance, one entire sub-group fails to respond to a survey, the results will be skewed. In this study there were three sub-groups: curriculum writers, textbook writers and teachers. Teachers involved in the study work both integrated and subject-specifically.

5.2.3 Validity

The validity of a qualitative study has five validity criteria, according to Larsson (1993). The five criteria are; discourse criteria, heuristic value, empirical anchorage, consistency and a pragmatic criterion. Besides the validity criteria, Larsson mentions three criteria for quality in a qualitative work as a whole; perspective consciousness, internal logic and ethical value. Three criteria about the quality of results are also mentioned; richness of meaning, structure and theory development. Interviews are dependent on validity at all stages of the interview according to Kvale (1997). In dealing with the research question thematically, validity is dependent on the theories and logic in deriving research questions from theory. When it comes to planning and choice of methods, the knowledge produced is valid if it has a minimum of harmful consequences: in the actual interview the meaning and control of information given is important, in transcription of interviews it is necessary to consider word choice, how transcripts are made and when analysing and assessing results, a second assessment is needed to validate results.

In the qualitative analysis of the second study in this thesis, the first five validity criteria mentioned by Larsson have been considered. The question of integrated and traditional science is well immersed in the discourse on Science education. A description of how teachers plan and interpret curriculum in terms of integrated and subject-specific science education in
Swedish has not been made earlier, so a heuristic value occurs. The empirical anchorage is satisfactory, since the schools represent different ways of working. The consistency is satisfactory since the schools represent a single town and pragmatic criterion can be evaluated by teachers who recognise the classroom situation described in the second paper. The three criteria of quality have been strived for in the entire work, since I have chosen a perspective from my own and others’ experiences of teaching science in compulsory school. The internal logic in explaining the problem with integrated and subject-specific teaching has been made from different views, both theoretical and practical. Ethical considerations have been taken into account at different stages during the course of implementation of the study, when interviewing teachers and while writing the article and analysing and presenting data. The last criterion about quality of results has been expressed through our ambition to get a rich description of the different schools’ ways of performing science education, by creating a good and easy structure to describe teachers’ works and by trying to find a way to connect to the theory of integrated and subject-specific education.

Of course, validity criteria have also been considered in other qualitative data collections and in analysis of the piloting of questions for the PISA 2003 and PISA 2006 studies, in developing the experts’ study and in analysing results from the experts.

### 5.2.4 Reliability

One of the things that influences the results of the study are the questions asked in the interviews. Since the interviews were semi-structured, there can be differences in questions posed to the informants. If informants get different questions, it is probable that they answer differently and emphasise different problems and areas. This is the main problem when using semi-structured interviews like those in this study. One question to ask when doing interviews is ‘Have things been done with reasonable care?’ (Miles & Huberman, 1994, p. 278). Diachronic reliability\(^{12}\) may be valued as high in this study in reference to the teachers’ examples of planning and the teaching situation. A teacher makes plans and works in accordance with the plan in a systematic way. A teacher who has worked some years in the same subjects with the same year group of students usually finds a normal state of lesson planning. Synchronic reliability\(^{13}\) may be lower, since teachers’ view of what is integrated and subject-specific may be poorly defined according to the difficulty of socially negotiated facts (see above). We tried to take each step in the interview process as carefully as possible. We prepared some basic questions for the teachers to concentrate on. If teachers answered a question in an interesting manner, the subject was asked to develop a more substantial answer. What was judged as interesting depends of course on what the researcher is interested in, based on pre-existing views brought to the interviews. The researcher is therefore an essential part of the research instrument, as in all qualitative research.

In the teacher interviews there are results that could have been predicted regarding what teachers do when they plan teaching, such as using the textbook, making a year plan or planning different year groups according to research literature. Other results are new, such as the use of mind maps by teachers as a planning instrument and the fact that students do not recognise the organisation of science education. To both find old ‘truths’ and new views is a quality of the qualitative form of study. The possibility of confirming known facts and finding new descriptions is a factor of reliability.

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\(^{12}\) Stability of observations over time  
\(^{13}\) Stability in the same time frame
The reliability of the sampling and data collection is essential in the treatment of data, also when it comes to statistical treatment of data. Reliability of the analysis of results of the student survey is associated with the statistical strength of the analysis. The Mann-Whitney’s U-test has a high strength if the sample does not fulfil criteria for a t-test (Henriksson, 1999, p. 99). Of course, the question of what students really mean may be posed, since questions can be misinterpreted. This has not been further investigated in this study. To know more about what the students really mean by their answers would involve a deeper interview study. The judgement of this study is that students have answered the questions in the best manner with exceptions discussed in paper 2.

A discussion about the four grade Likert scale is also obvious. Why use four grades and not more steps on the scale? Why aren’t categorical groups used, when there is a scale? These are questions that may be posed in this discussion. Our judgement is that, since many of the other questions in the main study used a four grade scale, there is a good degree of accuracy in using a four grade scale.

5.2.5 Generalisation
In the light of the small size of the case examined in study 2, it is impossible to draw conclusions for the total population; at any rate, this was never the intent of this study, according to the case study methods (Yin, 1994, p. 30-32). The intention was to discover specifics regarding the case. The sample is a special case of schools since they worked with a project focused on no set timetable. This gave the schools more opportunities than normal to work with freedom in planning and performing Science education organisation and content. The study is an example of how schools work when they have the opportunity to abolish a timetable. The focus is on Science education and it consists of examples drawn from four teachers’ stories about their planning and teaching. Even though it is not possible to generalise this study to all schools in Sweden, the possibility of richness of meaning in the study might lead to recognition from teachers that work in schools that this is a meaningful story to read. In that case both pragmatic validity and empirical anchorage criteria described in Larsson (1993) are fulfilled.

5.3 Ethics
The aspects of ethics in research concerning individuals are discussed. In Sweden, the research community has agreed on some recommendations for human and social research through the Swedish Research Council (Vetenskapsrådet, 2002). In these recommendations, four main demands are placed: the information demand, the consent demand, the confidentiality demand and the right to use demand. Two recommendations are also posed by the Swedish Research Council: one is that the researcher should give informants the opportunity to read ethically sensitive parts and interpretations before the report is published. The other recommendation is that the researcher should inform informants and other involved persons where the research will be published and they should receive a report or summary.

In a large-scale project like PISA with so many people involved, there are special issues to consider when information about the research study is disseminated. In the PISA project, students receive information sent to them before the assessment instruments are distributed to them and the assessment takes place, at least in the main study. The sampled schools of the PISA study are obliged to participate, since assessment is managed by the Swedish National Agency for Education. The internationally large-scale assessment is used as a part of the national evaluation system. Parents of students have the opportunity to withdraw participation if they find it uncomfortable or not suitable for their children to be assessed. In the survey
performed after PISA 2003, schools that answered the questionnaire that I sent to them in study 3 were not obliged to answer this specific survey, so the response rate of 77 percent of possible schools is a satisfying result. The school answering rate from PISA 2006 indicates that it is better to get all the questions at the same time to achieve a high response rate. Students’ results from the PISA assessment are made anonymously and no personal results are published.

In study 1, experts who were asked to contribute received a letter informing them of the aim of the study and they were given the opportunity to withdraw their answers. In study 2, teachers were informed orally about interviews and could refuse to be interviewed. The schools and teachers are presented anonymously in the presentation. Finally, data gathered in the study is not presumed to be particularly sensitive for the informants. Potentially sensitive data concerns individual students and their results. This is handled with care and confidentially throughout the PISA process.

6. Results

As apparent from above, this thesis consists of theoretical studies of literature on integrated Science, and contrasts integrated Science with traditional Science (or subject-specific Science). Traditional Science education is described in the literature as common Science education, well known to all, and this form is contrasted with other ways of working; this as well as several models of integrated Science education are presented in Section 1. Figure 1.1 illustrates different slogans for integrated Science and desired outcomes of integrated (or progressive innovative) Science education found in the literature. Blum’s (1973) categorisation of the intensity and scope of integration is used to analyse these different slogans. Swedish curricula during the 21st century and how integrated Science is integrated into the contemporary national curriculum, together with a short review of previous research about the intentions of integration in the Swedish curriculum is described. Previous research regarding student results (both nationally and internationally) are briefly described. The frameworks of two international studies, TIMSS and PISA, are also briefly described. The PISA framework is analysed in terms of Blum’s categories of intensity and scope and the framework is found to fit well into an integration pattern, as seen in Section 2.2.3 and the discussion in Section 7.

As will appear below, this thesis also contains four studies which, taken together, address the question of how integrated Science education differs from subject-specific Science education and the relationship between student assessment results and the way Science education is arranged. Section 6 summarises the results of these four studies and sums up the four papers.

6.1 Defining integrated Science education in Sweden

The first two studies investigate what teachers and others interested in Science education mean when they discuss integrated and traditional Science education. The investigation explores the special features of integrated Science in Sweden. The first study is an account of experts’ opinions on Science education, based on their responses to integrated Science education statements taken from theories of Science education gathered from the literature on integrated Science. One aim of the experts’ study is to contrast the theory of integrated Science education with a Swedish context. The second study is a case study of four schools in a city in Sweden. Both integrated and subject-specific Science are taught in these schools and they all share the same local curriculum. Both arrangements of science education are
presented and illustrated. Below follows a section from each study in which results are developed.

6.1.1 The experts’ view of integrated Science education

The aim of the first study was to find, explore and further develop the concepts of integrated and subject-specific Science education in a Swedish context, through experts’ knowledge. This is achieved by studying the opinions of 24 experts on curriculum and Science education. 18 experts responded and the remaining six experts did not answer the statements. These six informants were contacted in different ways (telephone, e-mail), although one expert was abroad and not possible to reach. Three experts contacted by telephone gave different reasons for not answering. Some of the reasons were on principal, while some said that it had been so long since he had worked in schools that his experience was out of date. Three informants sent in a survey with partial answers to questions.

The study aims to investigate what these experts mean when they use the term integrated Science. The experts are all familiar with the Swedish school system and its trends, either through work in schools or through the debate regarding integrated Science. They expressed opinions on the practical implementation of Science drawn from their own experience and they expressed opinions about integrated Science education as opposed to subject-specific Science. As a first step in the experts’ study, the 24 informants anonymously evaluated 30 statements about integrated and subject-specific Science education. In a second survey, the same informants were presented with the means and medians of their aggregated answers from the first step; they were then offered the opportunity to change their answers if they wished. Providing informants with the opportunity to revise their answers after having seen answers from the whole group is a way of achieving answer stability (Murry jr & Hammons, 1995).

The results of the first survey are presented as a table which shows each statements means, medians and standard deviations (see Table 2, Paper 1). Informants’ answers are discussed and compared to the theory behind the questions. Statements are grouped into four categories: work forms, content, reason for integration and target group. The distribution of the statements into these four groups is found in Table 1, Paper 1. When analysing statements with extreme values (in the sense that informants either strongly agreed or strongly disagreed), two of the statement categories were picked more often than the other two. The statement categories that informants had strong opinions about dealt with content and reason for integration, although there were few statements about content. The statement category which informants most often agreed with dealt with content. Informants both agreed and disagreed with the statement category reasons for integration.

Several conclusions may be drawn from the experts’ survey. To begin with, we investigated statements that informants either agreed or disagreed with. The informants agreed with eight statements. The informants disagreed with five statements. The informants are neutral to seventeen statements in the survey (scores in the test instrument between 2.0 and 3.0). Eight of these seventeen statements dealt with the content of integrated versus subject-specific Science education and the informants’ preference for integrated or subject-specific Science education. Of the statements that informants were neutral to, four dealt with different ways of working with Science classes. The remaining statements with neutral responses dealt with the alternative ways of working with Science classes.

\[14\] Agreement is accomplished when the mean value from the group of informants is lower than 2.0 and disagreement is accomplished when mean value is higher than 3.0.

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purpose of integrated Science education and its target groups. When the informants neither agreed nor disagreed with a statement, the response was treated as indicating that the informants lacked a strong opinion on that subject. Since this seemed odd in some cases, it is commented on in the discussion, see section 7.1.2.

The statements were formulated based on literature regarding integrated Science education. Informants most highly agreed or disagreed in the statement categories content and reasons for integration. The survey’s main results are that, experts state that there exist differences between integrated and subject-specific Science when it comes to approaches to students’ everyday conceptions. These everyday concepts are not apparent when it comes to statements regarding subject-specific Science. Informants were in agreement that integrated Science works with themes and that integrated Science education, unlike subject-specific Science, contains a stage where teachers provoke students to challenge their ideas about a phenomenon. The informants also shared the opinion that integrated Science requires as much resources as subject-specific Science.

A second study, Paper 2, gives more information about the comparison between integrated and subject-specific Science education by providing an investigation of a real classroom situation in which teachers and students were invited to express their views on Science education. A comparison between what the literature and the experts’ study have to say about integrated and subject-specific Science education is presented in section 6.1.2, where it is contrasted with information about teachers’ practice, as exemplified by the below case study.

6.1.2 A case study of four schools in a Swedish town

The results of the case study show that teachers’ views are concentrated on planning and content and that these views differ among teachers. Students’ views are concentrated on three questions regarding integration of Science: themes in Science; themes in Science and Social Science; and textbooks for all three Sciences. The study used different data sources: interviews with teachers, classroom observations, a school survey and student questionnaires. Teacher interviews were qualitatively analysed for integrated or subject-specific Science, and student questionnaires were statistically analysed to compare student views on thematic work.

Two of the four schools are integrated schools, one is subject-specific and one is mixed. Different views on planning and teaching are described in Paper 2, based on interviews and classroom observations, with examples of how teachers work. Teachers as a team plan for an entire year in both integrated and subject-specific schools. Planning takes place at one or more meetings annually. Individual lessons are planned by each teacher. This planning framework was present in all three school types. The most striking difference between the schools was that the integrated schools worked with mind maps when planning. These mind maps were either produced before the school year or they were created together with students during the school year. Another difference involved the use of projects or themes at integrated science education. The subject-specific school does not use mind maps when planning, although the teacher sees a comprehensive connecting thread which extends over the various lessons. Analysis of student answers indicates that student views in subject-specific as opposed to integrated Science do not coincide with the teacher’s. More details on this appear below of the section and in Paper 2.

A second analysis of the results in Paper 2 uses a conceptual framework borrowed from the TIMSS study. In this, three levels are employed: intended, implemented and attained
curricula. One of the ideas behind this conceptual framework is that education in a school exists in an environment larger than the school.

**Intended curriculum**
The intended curriculum is Science as defined at the national and school level. National curricula in Science (Biology, Chemistry and Physics) permit integrated teaching and subject-specific teaching. Teachers are free to choose how to work and there are no centralised instructions. The context for the schools in Paper 2 is the national, municipal and school level curricula. All four schools share a common national and municipal curriculum but differ when it comes to school curriculum. The emphasis in this study is placed on the implemented curricula at the school level through interviews and observations and the attained curricula through student tests and questionnaires.

**Implemented curriculum**
The national, municipal and school level curricula are connected since the municipal curriculum presupposes the national curriculum. Differences in school conditions (e.g. organisation, economics and human resources) require planning in accordance with actual circumstances. This study focuses on teacher planning of Science and work with Science in practice. Science curricula are handled differently at the four different schools, as described in Paper 2. The two integrated schools develop their local curricula over several occasions, both individually and in teacher teams. The subject-specific school places the local curriculum in a loose-leaf binder on a book shelf and does not refer to it during daily lesson planning. In this case, the textbook determines the organisation and content of teaching in Science. At the two integrated schools, time spent on Science education varies according to the kind of activity being performed in the class. Lessons outside of school require the allotment of a larger amount of time to Science, while less time may be allotted to ordinary lessons. The teacher’s experience at the subject-specific school is that less time is allotted to Science when other events is set in, which causes some Science topics to be excluded. While the teacher at the subject-specific school feels time is too short, teachers at the integrated schools do not experience a lack of time for Science lessons.

The implemented curriculum is Science content presented by teachers to students. It takes place in the school classroom or as organised outdoor activities. There are differences between integrated and subject-specific schools when it comes to long-term planning. The integrated schools in the study use mind maps to illustrate content and topics to be studied for their students. Students create the mind map themselves at one of the integrated schools while at the other integrated school the teaching team makes the mind map and posts it on the classroom wall for students to reflect on. Student involvement is a crucial part of planning at one of the integrated schools. At the other integrated school, the teacher did not refer to student involvement in his interview, although he related that he had many discussions with students about what they think during lessons. In the subject-specific school, textbook content serves as orientation. The teachers’ use of textbooks differs somewhat between the four schools. The teacher at the subject-specific school depended heavily on one textbook, while teachers at the other schools used various textbooks as a whole or as parts. One teacher at one of the integrated schools used various text sources, i.e. not just textbooks but also ordinary books, facts and narratives.

The implemented curriculum was examined through teacher interviews focusing on differences between integrated and subject-specific Science teaching. Some classroom observations were used as an additional source for comparing teachers’ accounts of their
classroom work with the implemented curriculum. Interviews with teachers are more expressive than observations concerning teachers’ aims and wishes. This is regarding how they would like to work, and if they display a clear preference for integrated or subject-specific teaching. Classroom observations didn’t provide clearly observable distinctions between integrated versus subject-specific Science, since a cursory investigation left the impression that many lessons are performed in similar ways. Observations showed that the teacher presents material to students, students work with the material and the teacher then summarises the lesson before the break. To this extent, both integrated and subject-specific Science use the same classroom pattern. It should be pointed out that this study did not follow a class continuously over a long period, so it is possible that some things were missed due to the brevity of the observations.

Attained curriculum
Attained curriculum refers to outcomes. This is what students learn and includes both knowledge (expressed as scores and test results) and attitudes towards a subject. In Paper 2 we investigate the lack of student clarity vis-à-vis teacher’s intentions regarding arrangement (integrated or subject-specific) in at least one school. In one school (A), students perceived an effort by their teacher towards integrated Science through the use of different themes. In another school (C), students perceived an effort by their teacher towards subject-specific Science without themes. In the two other schools (B and D), students did not perceive an effort from their teachers towards a particular arrangement of Science. One may ask, does it matter if students do not perceive their teacher’s efforts towards one or another form of educational arrangement in Science? It seems to have no consequence for their scientific literacy. But according to the PISA 2005 field trial the four schools students’ results were similar, so no differences were found between them, i.e. between the different arrangements of Science.

What signals do students get from the teacher regarding the subject? Paper 2 notes a difference in student responses between those who have experienced teachers and those who have less experienced teachers. Teacher experience may affect student confidence in expressing certainty in expressing views regarding integrated or subject-specific Science education, but it is not possible from this study to make a more general statement about a relationship between teacher experience and student answers regarding Science arrangement. Students with more experienced teachers are more confident in expressing their views on the arrangement of Science education (integrated or subject-specific) than students with younger and less experienced teachers, at least within these four schools.

Summary
The case study of four schools in a Swedish town illustrates at least three ways to arrange Science education. There are similarities and differences in teacher planning. The differences are most evident when it comes to the aim of planning and whether or not student involvement in planning is considered important. Planning devices and degree of student involvement differ among integrated, subject-specific and mixed schools. When observed superficially, the four schools’ lessons are remarkably similar. Although the question of whether the arrangement of Science (integrated versus subject-specific) affects fulfilment of objectives has not been extensively studied here, this study illustrates how integrated and subject-specific Science education work in practice.

15 The schools were chosen in the PISA 2005 field trial. The goal of the field trial was mainly to test questions that would appear in the PISA 2006 study. In testing scientific literacy for the field trial schools, school means were calculated from student means.
6.2 Statistical analysis of data from PISA 2003 and PISA 2006

A second part of this thesis deals with two statistical studies of Swedish PISA student results. In summarising the studies, we see that they involve hypothesis testing of groups based on educational arrangement (integrated, subject-specific and mixed Science). Hypothesis testing is performed to discover possible significant differences between groups when comparing mean values. This is discussed in Section 5.1.1. The first study, with PISA 2003 data, consists of a sample of 1,867 students and the second study, with PISA 2006 data, consists of a sample of 4,140 students. The first statistical study is narrower than the second when it comes to the areas of Science knowledge and affective domain. This is due to the fact that questions in PISA 2006 are more diverse than in PISA 2003, since PISA 2006 was more focused on scientific literacy as its primary domain of assessment.

Results from the PISA 2003 study are described first, followed by results from the PISA 2006 study. The main findings from both studies are summarised and contrasted.

6.2.1 Hierarchical Linear Model (HLM) analysis of data from PISA 2003

The first quantitative study contains data from a number of schools in the PISA 2003 study. This data deals with classes that work with integrated or subject-specific Science education as well as those that work with a mix of both educational arrangements. In this study, the variable tested is described, HLM models are explained, the model variables are described and various contextual factors at the schools studied are pointed out and analysed. For more details regarding the HLM study, see Paper 3 (Åström & Karlsson, 2007).

The independent variable (integrated, subject-specific or mixed Science education) for this study was collected at school level and as a group level variable at the schools. The study permitted variable testing at both individual and school levels. The arrangement variable was kept simple. The three arrangements of Science teaching were derived from data collected from the PISA schools. This made it possible to perform a simple first hypothesis test of the sample. The first hypothesis test was designed to reveal if student results differ according to Science arrangements. PISA 2003 schools were asked if they had thematic education or not. The answers indicated that, while some schools work exclusively thematically, others work exclusively non-thematically, still others work thematically in some groups and non-thematically in others and finally some schools switch from thematic to non-thematic Science education over the course of a school year. The schools that work thematically were categorised as having integrated Science, those that worked non-thematically were categorised as having subject-specific Science and the two final groups were categorised as having a mixed Science arrangement.

Mean results for these groups were calculated at the individual and school level. The Grand Mean (GM) and means of the Integrated (I) and Subject-Specific (SS) groups didn’t show much difference (for individuals GM: 508, I: 504 and SS: 507; for schools the GM: 506, I: 500 and SS: 506). The mixed group displayed a larger deviation from the mean (522 for individuals and 511 for schools), see Table 1, Paper 3. These deviations from the mean were not statistically significant since standard error was large for the integrated and mixed groups, due to that size of the groups were small. As a next step it therefore proved necessary to

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16 The school educational arrangement had to be considered due to inconsistency in labelling it. To find out more about the coherence between descriptions of teaching and grading at schools, we studied the extent of agreement between information about Science arrangement (classified in a survey in Autumn, 2003) and subject grades from Spring, 2003 (Åström, 2007, p. 28-29).
choose a more sophisticated analysis model to eliminate other variables that impact on student results (Turmo & Lie, 2004). A Hierarchical Linear Model (HLM) was chosen for this purpose. HLM takes variables with a large impact into account and makes it possible to discern smaller influences that would otherwise be difficult to detect.

The variables the three HLMs had in common were: sex (male or female), country of origin (Sweden or other), language at home (Swedish or other), preschool experience measured in time and an index of economic, social and cultural factors. This index was weighted from student answers to a number of different questions in the questionnaire. By evaluating the impact of these independent variables, it was found that the single variable language Swedish at home accounted for 32 PISA points (see table 4, Paper 3), or about a third of the standard deviation.

Three HLMs were tested on PISA 2003 data from Sweden. The models were similar to each other with the exception of the independent variable of teaching arrangements. The three models tested included the dependent variable (scientific literacy results from PISA 2003) and the affected outcome:

A) Without the independent variable (integrated, subject-specific or mixed Science).
B) With the independent variable.
C) With the independent variable and a fixed school mean of the effect variable.

Paper 3 describes the results for these three models (A boys = 518.7, A girls = 520.8, B boys = 517.4, B girls = 519.5, C boys = 516.8 and C girls = 518.9). These are the results for a student with language at home (Swedish), maximum preschool attendance and an economic, social and cultural index of 0.3 (the mean value of this index in Sweden). A summary of the results of the comparison of Science educational organisation with student results for the three models tested appears in Table 6.1.

<table>
<thead>
<tr>
<th>Model tested</th>
<th>Results of variable</th>
<th>Relation effecting</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Without the examined variable</td>
<td>No effect(^{17})</td>
<td>No difference</td>
</tr>
<tr>
<td>B: With the examined variable</td>
<td>No effect</td>
<td>No difference</td>
</tr>
<tr>
<td>C: With the examined variable and fixed(^{18}) school mean on the effect variable</td>
<td>No effect</td>
<td>No difference</td>
</tr>
</tbody>
</table>

Table 6.1 shows the absence of statistically significant effects for the examined variable. Table 7, Paper 3 shows the absence of differences in the models themselves after having calculated variances within and between models. With similar variances, all the models explain the dependent variable equally well when it comes to student Scientific literacy results. In conclusion, there is no significant difference in results between the models\(^{19}\) and this indicates that student scores on PISA 2003 are unaffected by Science arrangement. These

\(^{17}\) No effect means the same score as the reference model (or approximately the same)

\(^{18}\) School means are fixed in model calculations

\(^{19}\) When comparing school grades, the variable was sharpened, see Åström, 2007, p. 29. An HLM that takes into account this sharpened variable yielded the same results as those in the three models used in Paper 3, i.e. the absence of differences between student Science literacy results based on Science organisation.
results were unexpected and became the starting point for further analysis of the next data set, the PISA 2006 data in section 6.2.2.

6.2.2 Hypothesis testing of data from PISA 2006

The fourth study analyses students’ Science results in PISA 2006. By means of hypothesis testing (described in section 5.1.1), this study investigates the relationship (if any) between student results in the various competencies assessed in PISA 2006 and different Science arrangements. Three Science arrangements are compared: integrated Science, subject-specific Science and a mixed form. These three Science arrangements are compared to total Science literacy scores and three competency sub-scores from the PISA 2006 assessment.

The three competency sub-scores, ‘Explaining phenomena scientifically’, ‘Using scientific evidence’ and ‘Identifying scientific issues’ are further described in this section, according to the balance of subject domain content. PISA results are analysed at the individual and school level. PISA results for Reading and Mathematics literacy are also brought into the analysis to see if these factors influence Science results. Integrated, subject-specific and mixed Science education are also compared on the basis of the ESCS index and language at home.

The first conclusion suggests that student results for those who have integrated Science differ from results for students with mixed Science. These differences are reflected in total scores and two of the competency sub-scores: “Explaining phenomena scientifically” and “Using scientific evidence”; these differences appear when students are treated as one group, see Table 2, Paper 4.

The second conclusion is that the sample displays gender differences. When students with integrated, mixed and subject-specific Science education are grouped according to gender, differences between these science arrangements are pronounced among girls but non-existent for boys. Girls’ groups display statistically significant differences in Science literacy between integrated and subject-specific, and also between integrated and mixed Science. The differences are statistically significant at the five percent level in total scale and for the three sub-scales, see Table 4, Paper 4. Boys’ grouped into integrated, subject-specific and mixed Science show no differences in scientific literacy, see Table 6, Paper 4. Total and gender results are summarised in Table 6.2.

Table 6.2 Aggregated results from Paper 4.

<table>
<thead>
<tr>
<th></th>
<th>Difference between integrated and mixed</th>
<th>Difference between mixed and subject-specific</th>
<th>Difference between integrated and subject-specific</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined result</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Combined sub-scales</td>
<td>yes (2)</td>
<td>yes (1)</td>
<td>no</td>
</tr>
<tr>
<td>Girls total</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Girls sub-scores</td>
<td>yes (3)</td>
<td>no</td>
<td>yes (3)</td>
</tr>
<tr>
<td>Boys total</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Boys sub-score</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>

20 The three Science education arrangements are basically the same as those in Paper 3, se 6.2.1 regarding PISA 2003 data
21 Numbers in parenthesis are the number of sub-scales displaying differences at the five percent level.
Reading literacy has been put forward as a possible factor influencing differences in boys’ and girls’ Science and Mathematics results in the PISA assessment. Certain items may be characterised as boys’ items and others as girls’ items in the reading section of PISA 2000 (Roe & Taube, 2001). Girls and boys displayed differences in results in the TIMSS study for various Science domains (Whitfield, 1980). Girls and boys displayed differences in PISA 2000 as well, in the two sub-domains knowledge and processes, although gender differences could not be ascertained in overall scientific literacy (Kjaernsli & Molander, 2003). There are compelling reasons to analyse PISA 2006 results from the perspective of gender. When comparing results from students in integrated, subject-specific and mixed Science arrangements, gender was therefore brought into the analysis.

The study’s third conclusion is that reading literacy skills in this sample do not differ significantly for students in integrated, mixed and subject-specific Science, regardless of gender. There are gender differences in Mathematics literacy results for students in different Science arrangements. Mathematics literacy differs between girls in integrated, mixed and subject-specific Science, while boys do not display these differences between themselves.

The fourth conclusion is that there are differences between girls’ and boys’ mean ESCS in the different Science arrangements. In this study, girls with mixed and integrated Science education have a lower ESCS than girls with subject-specific Science. Boys with mixed Science education have a higher ESCS than boys with integrated and subject-specific Science. Using the calculated ESCS gradient explains an additional 3.8 PISA points, although this is insufficient to completely explain differences in mean scores between educational arrangements. Integrated, subject-specific and mixed arrangements are composed of differing student populations when it comes to the proportion of students with a language at home other than Swedish. This difference explains two PISA points, although this is insufficient to completely explain differences in mean scores between Science arrangements.

If it appears that one or the other gender is stronger in some domain, this may obscure the findings. Boys seem in fact to score higher in scientific literacy in the competency subscale ‘Explaining phenomena scientifically’ but girls and boys have reasonable similar results on the competency subscale of ‘Using scientific evidence’ and ‘Identifying scientific issues’ see Tables 3 and 5, Paper 4. A well-balanced assessment would balance different domains according to reliable test construction (Crocker & Algina, 1986). To investigate the item balance in the domains of content and application of the Scientific literacy of PISA 2006, the three scientific literacy competencies that PISA 2006 that are examined in Paper 4 are described according to the balance of different domains.

When competencies are grouped, we find that about 50 percent of the cognitive items assess the competency ‘Explaining phenomena scientifically’, 30 percent assess ‘Using scientific evidence’ and about 20 percent assess ‘Identifying scientific issues’. A way to further differentiate items is by categorising competencies according to application areas: ‘environment’, ‘frontiers’, ‘hazards’, ‘health’, and ‘natural resources’. An overview of items in each of these categories shows that, of the total number of cognitive items, the proportion of items dealing with ‘environment’ amounts to 19 percent, ‘frontiers’ 25 percent, ‘hazards’ 14 percent, ‘health’ 24 percent and ‘natural resources’ 16 percent. Table 6.3 presents the distribution over the three competencies.

22 The classification of item in PISA 2006 has been brought from the Norwegian PISA test centre.
Table 6.3 Percentage of different application items in the three scientific literacy competencies measured by PISA 2006

<table>
<thead>
<tr>
<th></th>
<th>Explaining phenomena scientifically (percent)</th>
<th>Identifying scientific issues (percent)</th>
<th>Using scientific evidence (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>17</td>
<td>25</td>
<td>16</td>
</tr>
<tr>
<td>Frontiers</td>
<td>26</td>
<td>21</td>
<td>26</td>
</tr>
<tr>
<td>Hazards</td>
<td>15</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Health</td>
<td>22</td>
<td>20</td>
<td>29</td>
</tr>
<tr>
<td>Natural resources</td>
<td>19</td>
<td>12</td>
<td>13</td>
</tr>
</tbody>
</table>

When compared to their proportions among the total number of items, the application ‘Health’ is overrepresented in the competency ‘Using scientific evidence’ and ‘Environment’ is overrepresented in the competency ‘Identifying scientific issues’. Aside from these two applications, the spread of different applications over the various competencies is fairly equal to the applications’ overall percentages. Another way of dividing the three competencies is by sorting them into the area knowledge of science, i.e.: ‘earth and space systems’, ‘living systems’, ‘physical systems’, ‘technology systems’ and the area knowledge about science, i.e.: ‘scientific enquiry’ and ‘scientific explanations’. These areas may also be examined according to the overall proportion of items in these areas and their distribution within the three competencies.

These results are found in Table 6.4 that shows that the area knowledge of science constitutes a large part of the competency ‘Explaining phenomena scientifically’. Almost half of the items in this competency are taken from the knowledge domain ‘living systems’. All items in the competency ‘Identifying scientific issues’ comes from the area knowledge about science, specifically ‘scientific enquiry’. In the competency ‘Using scientific evidence’, most items (68 percent) come from the area knowledge about science, specifically ‘scientific explanations’. Another large group of items in ‘Using scientific evidence’ is ‘technology systems’.

Table 6.4 Number of items in knowledge of science and knowledge about science in the three scientific literacy competencies measured by PISA 2006

<table>
<thead>
<tr>
<th></th>
<th>Explaining phenomena scientifically (Nr. of item)</th>
<th>Identifying scientific issues (Nr. of item)</th>
<th>Using scientific evidence (Nr. of item)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth and space system</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living system</td>
<td>24</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Physical system</td>
<td>15</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Technology system</td>
<td>2</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Scientific enquiry</td>
<td></td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>Scientific explanations</td>
<td></td>
<td></td>
<td>24</td>
</tr>
</tbody>
</table>

In the above description of different applications and knowledge domains of Science there are not obvious why boys would score higher than girls in the competency of ‘Explaining phenomena scientifically’, unless boys know more in the knowledge of Science domain. Girls and boys seem to do equally good (or bad) in the other competencies. Total results and girls’

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23 Total percentage does not equal 100 because some items are classified as ‘other’
results differ according to Science arrangement (integrated, subject-specific and mixed). Boys’ results in these educational arrangements do not differ. An explanation of these differences based on item content would require deeper analysis at the item level.

**6.2.3 Concluding results from the two statistical studies**

Results differ between the two statistical studies discussed in this section of the thesis. Paper 3 found no differences in student results in scientific literacy based on data collected from the PISA 2003 study, in the sense that different Science arrangements (integrated, subject-specific and mixed) did not display differences in student results. Paper 3 did not discover any significant difference between student results on the basis of gender, when gender is used as a background variable in HLM analysis.

In the study of PISA 2006 data, however, some small differences appear when it comes to total results for the different Science education arrangements, and it was of interest to further analyse this. That was done by looking at background variables and at different sub-categories. The difference occurs between total results for integrated and mixed Science organisations in two specific sub-scores. When gender is taken into account, differences in results are more pronounced between different Science education arrangements. Girls display statistically significant differences in total test results and in three sub-score competencies when girls with integrated Science are compared to girls in subject-specific Science, and when girls with integrated Science are compared to girls with mixed Science. No differences are found among boys in the different Science arrangements.

Comparing the two studies, the PISA 2003 data was analysed both by comparing means and by applying hierarchical linear modelling. The PISA 2006 data was analysed by comparing means for different groups. Similarities and differences between these two studies are explored in Section 7.2.

**7. Discussion**

Integrated Science education and the PISA framework that supports integrated Science education learning was described and discussed Section 1 and 2. Blum’s model of intensity and scope includes integrated Science curriculum. TIMSS’ framework focuses on subject-specific Science education. Since this study focuses on questions related to integrated Science education, the PISA data was chosen. At the student level, arguments for integrated Science education include understanding, interest, involvement and usefulness.

The sections that treat qualitative data investigate the meaning of integrated and traditional subject-specific Science education in Sweden. From the standpoint of theory, this section describes similarities and differences in how Swedish educational experts view integrated vs. subject-specific Science education. It also describes similarities and differences in how teachers of integrated versus subject-specific Science implement local Science curriculum. The quantitative section goes on to explore differences between student results in scientific literacy (taken from the Science section of the PISA assessment) when students with integrated Science are compared with students with subject-specific Science education.

The first section contains a discussion of the qualitative studies. After this, there is a discussion of the statistical analysis and its results. Similarities and differences in experts’ and teachers’ views on integrated Science education are compared with theory. Similarities and differences in the two statistical studies of PISA 2003 and PISA 2006 data are discussed. Explanations of the results are presented as well as suggestions for future research.
7.1 Compulsory Science Education in Sweden

Although a comparison of two Science educational organisations may appear to be a straightforward and uncomplicated task, especially when based on data taken from a standardised international assessment such as PISA, however this is far from the truth. How to integrate are not trivial questions. Integration differs in different settings and there is no simple template for this educational arrangement. With the exception of a few small innovative projects in various locales and a single large school project that deals with schoolwork without set timetables (SOU 2005:101, 2005) studies of this aspect of Science education in Sweden are noticeable by their absence.

The debate about the curriculum reached its height in the mid-1980’s. The group around Professor Ingelstam in Linköping (Ingelstam, 1985; Riis, 1985) has produced what may be the most exhaustive study of integrated Science curricula and the aims of Swedish curricula. This group studied curricula in Swedish schools and analysed their content from the perspective of integrated education. They also investigated the development of Swedish curriculum and ideologies that influenced Swedish curricula in the 20th century. Their work does not, however, describe exactly what teachers mean when they speak of integrated Science curricula. This aspect is relevant when analysing student results in Science knowledge and attitudes towards Science and Science education.

The group around professor Andersson in Gothenburg has studied students’ Science results and students’ attitudes towards Science (Andersson, 1994a). Their results are limited by the fact that the questionnaire does not distinguish between teachers working with integrated and those working with subject-specific Science. When dealing with integrated versus subject-specific Science, it is relevant to ask if participation in a specific educational arrangement influences teacher views on the nature of educational organisation.

It was therefore important to learn more about how teachers interpret integrated and subject-specific Science education and the relationship between these two Science arrangements and student results in scientific literacy.

7.1.1 Experts’ view of Science education

This section contains a discussion of the construction of the experts’ survey and survey results from the perspective of the theories involved. Results are grouped according to the experts’ level of agreement (agree, disagree or neutral) with survey statements.

Results of the experts’ survey

The results show that informants agreed or disagreed with some of the statements in the survey. More than half of the survey statements were met with neutrality. In the following text, results are presented and the informants’ level of agreement is discussed and reflected upon in the light of theory.

Agreement

Informants are clear that integrated Science involves thematic teaching of concepts such as energy or drug abuse. The content of integrated Science is the same as in subject-specific Science but structured differently, with themes in integrated Science. Drug abuse is one of the themes in the compulsory curriculum of 1980. Many experienced teachers make great use of this theme, since the current curriculum, unlike previous curricula, lacks concrete suggestions for thematic work. Energy is a theme developed by Andersson in his work on concepts for
compulsory schools in Sweden (Andersson, 2001). The energy theme is also fairly well represented in Science textbooks at the lower secondary school level.

Informants were also in agreement on elements that define integrated Science education: integrated Science challenges students’ everyday beliefs and develops student knowledge better. This position is unsurprising. Most work done in Sweden on the development of new and interesting forms of Science education deals with everyday beliefs (Andersson, 2001; Strömdahl, 2000). In the introduction to his report, Andersson writes that both subject-specific knowledge and an integrated understanding of environmental and resource questions are necessary for knowledge integration (ibid, p. 7). The difference between students’ conceptions of concepts interpreted as either Science concepts or everyday concepts is illustrated by several narratives in the anthology by Strömdahl et al. The suggestion that everyday concepts are more connected to integrated as opposed to subject-specific Science, as informants’ responses suggest in this study, is not clear from other sources.

Informants agreed that students will learn Science better in both integrated and subject-specific Science if they work hard to solve problems and do practical work. This is not strange, since it is a commonly held belief that hard work leads to better learning. This researcher expected, however, that the experts would indicate that subject-specific Science requires more hard work than integrated Science, since specialised Science education has a long introduction phase. According to Bernstein

“The specialized form of collection, indeed any form of collection, involves a hierarchy whereby the ultimate mystery of the subject is revealed very late in the educational life. And education takes the form of a long initiation into this mystery.” (Bernstein, 1975, p.82)

Informants agreed that integrated Science education provides students with greater security in a social context, better basic knowledge and that it generates more interest in Science. Yager & Lutz (1994) write that the ‘how’ of Science teaching is an aspect connected to differences in Science teaching and learning. It is however from this study unclear exactly what this ‘how’ is and does. The two statements in the survey that deal with integrated Science as a motivational factor for students might also be considered as statements that treat the ‘how’ of Science education. One of these two statements has to do with whether integrated Science adjusts to student interests better than subject-specific Science.

**Disagreement**

Informants disagreed with five survey statements. To begin with, they disagreed that one of the reasons for implementing integrated Science is that it saves on costs. Teachers in informal discussions often put this argument forward as justification for their opposition to integrated Science. In the 1970’s, Brown argued that cost-saving was a good reason for implementing integrated Science education (Brown, 1977). But in the survey one informant even suggested that integrated Science requires more resources than subject-specific Science.

Informants disagree with the statement that all Science students should learn the same things. This answer is difficult to interpret because the statement is open to several possible interpretations. Does the interpretation deal with that there is no individualisation of student prerequisites? Does it mean that all students have the same Science knowledge needs and they therefore should learn the same things? Or does it mean that, since students and their prerequisites differ, they need to learn different things to end up with the same knowledge? It
is difficult to determine which interpretation experts used when they expressed their disagreement here.

The informants also disagreed with other statements. They disagreed with the statement that subject-specific Science challenges students’ ideas about Science and that students are asked to modify their explanations of concepts. It is possible that informants disagreed with this statement because they think ‘challenging students’ ideas’ is not specific to subject-specific Science but is common to both educational arrangements.

Finally, the experts disagreed with the statement that subject-specific Science suits low performance students better than high performance students. This is also not consistent with research by Bernstein (2000). According to him, lower-class students do better with collected code than with integrated code. However, the statement is consistent with a study of middle-class mothers by Brantlingner and Majd-Jabbari (1998), where middle-class mothers found progressive teaching more interesting and expressed a high level of support for this form of instruction since they

‘[…] recommend loosely-framed, child-centred, problem-oriented and multicultural educational forms, and advocate eliminating ranking systems in schools and society.’
(ibid p. 432).

In practice however, middle-class mothers want their children to have conservative teaching since

‘they need direct and systematic instruction in the culture of power in order to continue to excel over lower-class children and to compete with children in their own class.’ (ibid p.454)

Neutral
Informants were neutral towards seventeen statements. Five of these statements deal with ways of working with Science and how lessons are performed by teachers and students (statements 3, 4, 6, 7 and 8). It is surprising that the informant were neutral towards these statements. It was expected that this study would indicate differences in how work was done. The statement that subject-specific Science discusses student’s everyday experiences received a neutral response. This stands in contrast to the informants’ response that integrated Science develops and challenges students’ everyday conceptions as a way of promoting learning. Perhaps subject-specific Science is considered to be more abstract than integrated Science and is therefore unsuited to everyday applications?

Informants neither agreed nor disagreed with a statement about society’s need for students who have studied integrated Science. They were neutral to a statement that adult students require integrated Science to learn more effectively. It was expected that these two statements would generate more agreement or disagreement, since strong opinions on these matters have been expressed in the literature on curricula for integrated Science.

Informants neither agreed nor disagreed with the statement that all students benefit from integrated Science. They were neutral to the statement that subject-specific Science better suits high performance students. A greater degree of agreement or disagreement was also expected from these statements.
Two statements receiving neutral responses dealt with the nature of Science as reason for integration. One statement was that, since Science is unified, Science education should be integrated. The other statement was that, since Science is fragmented, Science education should be integrated. These statements were expected to receive a greater degree of agreement or disagreement than the results indicate, since philosophical discussions of these matters address the issue of the unification and fragmentation of Science.

The main result of the expert study is that integrated Science is considered to deal with themes and students’ everyday conceptions. These results were expected in the light of the literature and traditions found in Swedish schools.

7.1.2 Case study
This section deals with methodological issues and the main similarities and differences found in the study. A case study was performed to illustrate how teachers work with integrated and subject-specific Science in reality. This exploratory case study took place at an early stage of the research. Its exploratory character is expressed in one of the study’s aims: to describe integrated and subject-specific Science in the light of theories and conceptions regarding the two educational forms. Teachers’ statements about planning and teaching Science are related to theory regarding integrated and subject-specific Science. In the analysis of this case study of four schools in a single town, the main focus is on integrated and subject-specific Science education. What do teachers really think and what do they do when they teach integrated and subject-specific Science? Schools were the basic elements in this multiple case study and teachers were the embedded units in the case. Schools were chosen as examples of different ways of organising Science education.

Science education in its various organisational forms was the object studied. Data was analysed within Bernstein’s (1975) theoretical framework. Bernstein defines integrated and collected codes in schools and describes their forms of expression. In the integrated code, teachers work horizontally and the time between problem identification and problem solution is short. Many solutions are made by the teaching team together with students, without the involvement of principals or other authorities. In the collected code there is more hierarchy, with little or no connection at the horizontal level between teachers. Since schools have different approaches to Science education and since teachers are known to hold different views about how Science should be taught, the four schools in this study provide insights into the possible forms Science education can take within a single curricular framework (the municipal curriculum). Differences and similarities in the case study results are discussed in this section.

The primary difference between teachers in schools with integrated Science and teachers in schools with subject-specific Science may be found in their perspectives on planning. At schools with integrated Science, teachers work with mind maps when planning and with projects or themes. The mind maps are thought to involve students in planning and provide students with a sense of ownership of the problems dealt with in lessons (Secules, Cottom, Bray, & Miller, 1997). Student ownership of the curriculum may be connected with Hopkin’s idea of experienced curriculum (Hopkins, 1940). Hopkins’ position is that questions should be owned by the learner and that learning should lead to experiences that are more than remembering, memorizing and (possibly) forgetting facts learned soon after the learning is completed.
In this case study of four schools in Sweden, the planning of Science classes in integrated and subject-specific schools differs due to differences in aims regarding student involvement and ownership of school work (Åström, forthcoming). Providing students with a sense of ownership coincides well with PISA benchmarks for real-life problems and willingness to engage in scientific enquiry. The aim of student involvement and ownership also coincides with the intentions of teaching instructions for STS, referred to in Section 1.1.2 of this thesis. Applying the model of experts’ versus novices’ knowledge organisations as described by Bransford et al. (2000) and introduced in Section 1.1.4, the teacher in the subject-specific school is the expert and students are novices. In integrated and mixed schools the teachers still lead the work but the role of expert is not as clear as in the subject-specific school since ideas about the object of learning belongs to more than one person.

Paradoxically, similarities among the schools studied are also evident in the area of planning. Teaching teams at the different schools construct work plans together for the entire year. Planning takes place one or a few times per year. Teacher planning most often generates documentation of local curricula which may be used by individual teachers over the course of the year. At the level of lesson planning, teachers work for the most part on their own, in some cases referring to the teaching team’s plan and in some cases not. Yet another similarity among the schools studied is in the lessons themselves. Teachers start their lessons with an introduction, perhaps an exposition of the topic to be dealt with in the current lesson. This is followed by student work, either in the form of practical work or problem solving in a textbook or some other written material. The teacher rounds off the lesson by summarising what has been accomplished and assigning homework for the next lesson.

7.1.3 Findings of the essence of integrated Science education

Three themes found in the literature and previously described in Section 1.4 are treated here. They are: usefulness of Science education, student ownership of Science studies and fragmentation versus wholeness of Science. Each theme is discussed both from theoretical and empirical points of view based on the findings from the studies. The two qualitative studies are discussed in terms of similarities and differences discovered.

The first theme, usefulness of Science education, has several theoretical sources. Usefulness can mean any everyday content or context that is useful to adult learning, life-long learning or similar things. Everyday content connects to STS theories (Aikenhead, 1994b; Fensham, 1988a) regarding Science in contexts (Enghag, 2004), concepts in Science (Andersson, 2001), ‘Science for all’ (Fensham, 1985), public understanding of Science (Layton, Jenkins, Macgill, & Davey, 1993) and to some extent scientific literacy (Bybee, 1997b). Roberts’ vision II is found in the quote:

‘the character of situations with a scientific component, situations that students are likely to encounter as citizens.’ (Roberts, 2007, p.730).

Roberts writes about the usefulness of Science for adults. All these writers claim that everyday applications of Science content are essential to teaching and learning Science. But how do Swedish experts and teachers react to everyday applications?

There is some evidence in the expert study that experts associate everyday situations with integrated Science to a greater extent than subject-specific Science. They agreed with the statement that integrated Science education contains everyday applications, but they were neutral to the statement that subject-specific Science education contains everyday
applications. While Swedish experts don’t see much difference between integrated and subject-specific Science education when it comes to classroom work and lesson management, they do see differences when it comes to content based on everyday problems, where they maintain that integrated Science works with this content while subject-specific Science does not. In Paper 2, teachers presented their views on integrated and subject-specific Science education. Teachers at schools A and B presented few statements regarding everyday applications of Science (see Paper 2). It is possible these teachers could have been offering such statements but the interviews did not focus on this aspect. It is also possible that teacher opinions regarding everyday applications have been emerging in the interviews if this had been introduced into the interview questions regarding integrated Science education; this was not, however, the case. The established working form for Science in Sweden has changed and developed over time and it is at least possible that traditional subject-specific Science has adopted an approach that includes problems based on everyday applications of Science, as in integrated Science. One might ask if integrated Science education really is an independent educational form in Sweden or if it’s just a transformed version of traditional subject-specific Science education.

The second theme in this section deals with student ownership of learning. One branch of theory about integrated Science claims that student ownership of learning is essential to integrated Science. Student ownership of learning is an important component of STS theory (Aikenhead, 1994a). Hopkins’ theory of experienced curriculum places student ownership as a primary theme (Hopkins, 1937). Dewey’s theory of learning is also student-centred (Dewey, 1938/1997). What has this study found regarding student ownership of Science learning? At a superficial level, the main difference between integrated and subject-specific Science classes (according to the case study of four schools with five teachers) is that teachers who work with integrated Science involve students in planning activities to a greater extent than teachers who work with subject-specific Science. However, the degree of student ownership varies between the two schools with integrated Science. At School A, teachers are very involved in planning and they develop a local curriculum and mind map of content. At school B, students are expected to create their own mind map to plan the year’s theme. No evidence of student involvement in content planning exists at School C. The expert study also presents some evidence of the role of student ownership, in that the experts agreed with statements that integrated Science motivates student interest in Science to a greater extent than subject-specific Science and they also agreed on that integrated Science adjusts to student interests better than subject-specific Science.

The third theme for this section is fragmentation versus wholeness. Schwab (1964) has thoroughly discussed the structure of Science. According to him, one problem with the Sciences is the fragmented nature of the subjects. Scriven (1964) contrasts the structure of the Sciences with that of the Social Sciences, which he claims has an essentially different structure. According to Scriven, the various Social Sciences are embedded in one another and no single subject can stand alone without the others. It is curious that the expert study did not reveal them taking a stand on either of the statements presented regarding fragmentation versus wholeness of Science. One of the main debates regarding integration in schools in Sweden has dealt with ways of overcoming the fragmentation that comes about due to the compartmentalisation of students’ days into small time slots (SOU 2005:101, 2005; Westlund, 1998). As observed by Osborne & Collins (2001), it is possible that students experience Science as fragmented while teachers, with their expert view of the field, do not. In the case study, the two schools with integrated Science believed integration would help overcome fragmentation of school work. But the teacher at the subject-specific school also considered
fragmentation to be undesirable and had introduced a comprehensive connecting thread to counteract fragmentation. In other words, fragmentation is opposed by teachers at all the schools, each in their own way.

When comparing integrated and subject-specific Science education, one finds more similarities than differences. Planning in the four case schools displayed both similarities and some differences. The similarities included planning in teacher teams, which sometimes produce local curriculum documents. Planning of individual lessons is done by the teacher. Differences found in the case study included the use of mind maps at schools with integrated Science and different degrees of student involvement. The school with subject-specific Science does not use mind maps. The experts’ study indicates that the aims of integrated and subject-specific Science are similar (they are at the very least neutral in their answers on this point). The experts recognise a difference between integrated and subject-specific Science when it comes to the use of themes and everyday conceptions, which is seen as specific to integrated Science. The lack of differences between integrated and subject-specific Science education in Sweden in the two studies is interesting, since some spokesmen of integration claim that there are huge differences between these two educational organisations.

‘Curriculum integration does not just mean doing the same things differently but doing something different. It has its own theories of purpose, knowledge, and learning and is able to stand on those without the necessity of standing on the corpse of the separate-subject approach.’ (Beane, 1997, p.43)

According to Beane, integrated education is not simply a curriculum that doesn’t separate subjects. Since our study finds more similarities than differences between integrated and subject-specific Science education, one is tempted to ask how important these similarities and differences really are. Are they of crucial importance to teaching practices and student learning?

7.2 Discussing the results of the statistical analysis of data from PISA 2003 and PISA 2006

The aim of the statistical analyses of data from PISA 2003 and PISA 2006 was to find if there are differences in students’ scientific literacy results depending on Science educational organisation (integrated versus subject-specific Science). The two statistical analyses of data from PISA 2003 and PISA 2006 yield partially different results in answer to this question. One shows no differences in student results based on the kind of Science arrangements. This is the case even when other factors are taken into account; factors such as an economic, social and cultural index and home language (see Study 3). The other study shows differences in students’ scientific literacy results based both on the kind of Science arrangements (integrated or subject-specific Science) and on gender (see Study 4). Study 4 also shows that students in the various Science arrangements (integrated, subject-specific and mixed) have different mean ESCS and different percentages of students with another language at home when grouped by gender. It is therefore not trivial to say that one analysis displays no differences while the other displays differences. It is possible that some of the noticed differences in student scientific literacy results, found in Study 4, came from differences of mean ESCS and the presence of students with another language at home. This is discussed in Section 6.2.2.

In this discussion some similarities and differences are described and discussed as ways to achieve understanding of the differences in results in the two studies. Thereafter some interpretations of the differences between boys and girls found in paper 4 are discussed.
Lastly, issues other than assessment issues that could help explain differences in results between the two studies are discussed. Despite all of this, it still remains a fact that PISA 2003 displays no differences based on Science arrangements while PISA 2006 displays some differences.

### 7.2.1 Similarities and differences between PISA 2003 and PISA 2006 data

This part of the study discusses similarities and differences between the two studies that might influence results.

The first similarity is that the two studies both are part of a large-scale international study. The main framework that measures scientific literacy is the same in both studies, see the quote in Section 2.2.2 of this thesis. The sampling, collection, analysis and processing methods are essentially the same in both studies. Another similarity between the two studies is that students have followed the same national curriculum, i.e. the Swedish curriculum from 1994, with courses established in 2000. Yet another similarity is that categorisation of schools into integrated, subject-specific or mixed Science arrangements occurs roughly in the same fashion. The analysis in the two studies involves hypothesis testing of groups to ascertain differences between groups.

Differences between PISA 2003 and PISA 2006 include the fact that the domain of Science content differs between the two studies; in PISA 2006, Science was the main domain, which made it possible to assess a greater section of the Science domain than PISA 2003. The two analyses differ slightly in their collection of the integrated / subject-specific variable; this difference is expressed both in the method of collection and in the way schools were permitted to answer questions. PISA 2003 asked schools to identify their Science arrangements about six months after the PISA 2003 main study had taken place, which resulted in the failure of some schools to respond to this. In the follow-up to the PISA 2003 main study, schools were asked to specify each individual group’s arrangement of Science education (integrated or subject-specific) for students in the 9th grade. This made it possible to determine if students who participated in PISA 2003 received integrated or subject-specific Science education at the individual level.

In the PISA 2006 study, schools were asked to categorise their Science education as integrated or subject-specific in the school questionnaire. Since the question was answered at the same time as the test, the reply rate for PISA 2006 was better than that of PISA 2003. However, the question itself was differently phrased in PISA 2006 as compared to PISA 2003. PISA 2006 asked schools to evaluate the proportion of integrated and subject-specific Science education in their school (the proportions were expressed as all, the majority, around half, the minority and none). In PISA 2006 this question had been altered compared to the question in PISA 2003 and posed with degrees of integration since the follow-up study after PISA 2003 demonstrated the possibility that a single school could implement different Science arrangements at different times or in different contexts. A school might, for instance, have one group of students with integrated Science and the rest with subject-specific Science education, or all the students might receive integrated Science some of the time and then switch to subject-specific Science education. It was therefore deemed appropriate to ask schools about the proportion of thematic lessons rather than their presence or absence. This formulation of the question may be a partial explanation for the increased reply rate in PISA 2006 as compared to PISA 2003. The five scale answers about proportions were later reduced to the three groups used in Paper 4; the two groups of schools with a small proportion of thematic studies were grouped together, the two groups of schools with a large proportion of
thematic studies were grouped together and the middle proportion was left as a group of its own. The categorisation of school answers differs between the different studies but when summarised, the proportion of schools with thematic, subject-specific or mixed teaching is to a great extent the same in both investigations.

A contextual condition that differs between PISA 2003 and PISA 2006 is that a debate about the pros and cons of integrated education has heated up again after a governmental report from 2007 entertained the possibility of grading different subjects in compulsory school (SOU2007:28, 2007). The draft of the report began two years before it later was published. It included curricular text analysis and analysis of different documents dealing with the current school situation.

7.2.2 Differences between boys and girls

Paper 4 discusses differences between boys and girls in results for scientific literacy, as well as differences among girls when grouped into integrated, subject-specific and mixed Science arrangements. Neither Paper 4 nor Section 6.2.2 has looked into how the gender differences are related to theoretical descriptions of Science arrangements. This section will deal with this.

One argument for differences between boys and girls test results is biological. Three biological arguments have been put forth to answer the question of why males excel at Mathematics and Science: males are more focused on objects from birth and are predisposed toward learning mechanical systems; male profiles show greater aptitudes in spatial and numerical cognition and this produces facility in learning Mathematics; and male cognitive abilities show greater variation and are therefore overrepresented in the upper levels of mathematical talent. However, research into the cognitive development of human infants, preschool children, and students at all levels has failed to support these explanations, according to Spelke (2005). Spelke’s theoretical review of research dealing with these three arguments found no proof to support them. Quite the contrary, Spelke pointed out that the evidence suggests gender parity in these areas, since both sexes share the same set of biologically based cognitive capacities for mathematical and scientific reasoning.

A second argument for differences between boys and girls in results may be gender related differences in cultural environments. An example of this is the culture of male and female students at a physics department in Denmark, described by Hasse (2002). In Hasse’s study, the approach to play as a part of learning academic material and assimilation into the academic culture are thoroughly discussed and analysed in the light of Engeström’s activity theory. Bernstein’s (1975) analysis of integrated and collected code is related to this aspect of differences. Bernstein describes collected code, especially in its specialized form, as a code that involves a hierarchy whose purpose is to cloak the subject in mystery or reveal it only late in educational life. There is a long initiation period into the subject. Bernstein maintains that partaking of knowledge making is something sacred in the collected code and this enhances the significance of the subject. Educational relationships are hierarchical and ritualized and the student is seen as ignorant, with little status and few rights. Bernstein sees a shift in emphasis in integrated curricula. Integrated curricula, according to Bernstein, shift from education in depth to education in breadth and from content closure to content openness. Overall content concepts concentrate on general principles. This effects education so that it emphasises ‘ways of knowing’ over ‘states of knowledge’. Integrated education shifts from education posed by a teacher in subject-specific education to self-regulatory education in integrated code. The results of this study show that girls do not benefit from integrated
Science education in Swedish schools. Boys’ results are not affected by Science educational organisation to the same extent as girls’.

A third explanation of differences between boys and girls in results may be gender differences in interests. One study in the U.S.A. involved sixth graders and a sample of 437 students who completed a survey designed to elicit student perceptions of Science and scientists. Results showed that for this sample there were significant differences between boys and girls in experiences, attitudes, and perceptions of Science courses and careers (Jones, Howe, & Rua, 1999). Studies in Nordic countries support Jones’ description, although later Nordic studies also include discussions on identity construction (Schreiner, 2006). According to these studies, interests differ according to gender.

The data in Study 4 is however not aimed specifically on gender differences. Therefore more data on what occurs in the classroom and student perceptions of classroom work need to be collected and analysed to come further with these questions.

7.2.3 Divergent results in the two statistical studies

One reason for the divergent results in Studies 3 and 4 when it comes to differences between boys and girls (or the lack of such differences) among different scientific literacy competencies may be the presence of ATI-treatment interaction. As discussed in section 4.2 in this thesis,

‘ATI is said to be present when for some group of persons an aptitude variable shows a different relation to an outcome variable in one treatment than it does in another.’


ATI can produce three different effects, discussed in Section 4.2. In this study there are two or three treatments: integrated, mixed and subject-specific Science education. There are also a multitude of different aptitudes to explore. In the first study (HLM-analysis of student results) we did not find differences between integrated, mixed and subject-specific Science education. Does this mean that educational arrangements do not influence students? The evidence did not support any differences in students results, even after simple mean value testing and analysis of other factors that could influence student results such as economic, social and cultural influences, gender and a language at home other than Swedish were taken into consideration. There may be reasons for this lack of difference. One possible reason for the lack of differences in student results based on Science arrangement is that the groups have more in common than differences. Some evidence for this is found in the case study and the expert study in this thesis. Socially negotiated facts are not always well defined and these definitions may change over time (Searle, 1997). The existence and content of integrated and subject-specific Science is a socially negotiated fact. There are also other probable technical (statistical) explanations for the lack of differences: differences may be too small to detect in the analysis; the sample may be too small; this particular sample may have lacked differences; or maybe aptitude-treatment interaction obliterates individual differences that otherwise would have appeared.

The differences found in the second sample are interesting but they also raise a number of questions. What reasons for the differences in PISA 2006 data can be found? Is aptitude-treatment interaction the main cause of differences in student results or are other factors involved? As discussed in Paper 4, there are differences in mean ESCS between groups: especially in the mixed group, both boys and girls display a statistically significantly higher
mean ESCS. Mean science results are higher in the mixed group for both girls and boys. Since the mixed group also has a higher ESCS, it is unsurprising to discover that the group has better Science results, since other studies show that higher ESCS is connected to better test results (Turmo & Lie, 2004).

Finally, it may be possible that we are looking at two different sets of data and therefore also at two different samples with different outcomes, and that these outcomes differ in a way that is impossible to investigate given the limitations of the collected data.

### 7.3 Further research

In this section some questions touched upon in the results and discussion sections are elaborated. Differences and similarities between subject-specific and integrated Science have been found in this thesis. There are things left unaccounted for. One is student involvement in teacher planning. Is it common for teachers of integrated Science to involve students in planning? Are teachers in integrated Science the only ones to involve students in planning? According to this study, teachers in subject-specific Science do not involve students in the same way. It would be interesting to learn more about these things. Should factors other than Science arrangements (integrated or subject-specific) be taken into account when considering student involvement, for example thematic planning?

How important is the everyday aspect in integrated Science education? Is it such a significant aspect that it justifies teaching integrated Science or is it an aspect that may well appear in both integrated and subject-specific Science education? According to many Science education writers, the question of usefulness or the everyday aspect of Science education is crucial to both Science subjects and school work. It remains to be seen if Swedish Science teachers share this view when they plan and implement work tasks.

A third question that arises has to do with the extent to which integrated Science is opposed to the fragmentation of Science. Does integrated Science prevent fragmentation? Does subject-specific Science prohibit a holistic view of Science concepts? The lack of information in the teachers’ interviews indicates that this area has not been sufficiently explored in Sweden. The expert study also showed neutrality towards statements dealing with fragmentation versus wholeness, indicating a lack of discussion on this topic among practitioners of the current curriculum.

Much work has already been done on the content of items and student results (Turmo, 2003), comparison of student results by country profile (Olsen, Kjaernsli, & Lie, 2005), comparison of item results by country profile in the Nordic countries (Olsen, 2005b), and comparison of scientific literacy results within some Nordic countries (Kjaernsli & Molander, 2003). It is possible to deeply explore research in the field of Science education based on data from student results in PISA 2006, which focused on scientific literacy. Earlier studies using data from PISA 2000 and PISA 2003 could not investigate how Science educational organisation effects student results in scientific literacy and student attitudes towards Science. This kind of study is now possible with the present data, both at the national and international level. To learn even more, research into the PISA data is required in the areas of classroom work and student attitudes. Further classroom studies are also required to determine what factors in the Science classroom influence student results in scientific literacy assessments.
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Thanks to Professor Karin Taube for letting me share some of her experiences with data collection for the PISA project, Professor Lisbeth Åberg for reading my thesis and her help on how to improve the readability of some sections, Professor Jari Lavonen for his insightful comments at a late seminar in the process of finishing the work. Interviews and classroom observations provided an understanding of how integrated and subject-specific Science education works in real classrooms. Many thanks go therefore to all the teachers interviewed for this study. Without their participation, data for the studies would not have been collected. I would also like to thank the experts who participated in the expert survey.

FoNTD, the Swedish National Graduate School in Science and Technology Education Research, started my PhD education. Thanks go to the head of the school, Professor Helge Strömdahl, for challenging my preconceptions about Science education and for his help in making me a better researcher. It has been most rewarding to come into contact with the global network of Science education researchers at FoNTD and to listen in on lectures and informal discussions.

I would also like to thank the doctoral students at FoNTD, especially the second cohort. We studied doctoral courses together and had lively discussions. Teachers at FoNTD have also contributed to these lively discussions and provided interesting thoughts about different aspects. A second doctoral group I found most helpful is the doctoral group in Educational research at Mid Sweden University, where I worked while writing this thesis. Thanks for the discussions and challenging debates about educational Science and for moments in the coffee room small-talking about this and that, the conferences and other details that life is full of.

Last but not least I wish to thank my husband for his support during my doctoral studies when I was away for long periods, travelling back and forth to Norrköping, Härrönsand and Umeå. Thanks for helping me focus on the writing during the later phases of this work.
List of papers

I
En Delphistudie av initierade brukares och användares uppfattningar om karaktärer av integrerad naturvetenskap i senare delen av svensk grundskola.
Åström, M. Submitted to Didaktisk tidskrift

II
Integrated and subject-specific Science education: Teachers’ and students’ views.
Åström, M. and Karlsson, K.-G. Manuscript

III
Using hierarchical linear models to test differences in Swedish results from OECD’s PISA 2003: Integrated and subject-specific science education
Åström, M. and Karlsson, K.-G. Nordina, 3(2), 121-131

IV
Differences in PISA 2006 Science sub-scales with integrated and subject-specific science education in Swedish compulsory schools.
Åström, M. Manuscript.
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Olsen, R., V. (2005a). *ACHIEVEMENT TESTS FROM AN ITEM PERSPECTIVE. An exploration of single item data from the PISA and TIMSS studies, and how such data can inform us about students' knowledge and thinking in science*, Oslo universitet, Oslo.


Umbildningsdepartementet. (1994a). Curriculum for the compulsory school system, the preschool class and the leisure-time centre Lpo 94. Stockholm.


### Table A1.1 Analysis of Brown’s description of integrated science in Blum’s categories.

<table>
<thead>
<tr>
<th>Intensity \ Scope</th>
<th>Within Subject</th>
<th>Between Science subjects</th>
<th>Basic/applied Science and Technology</th>
<th>Science and Society</th>
<th>Science and the Humanities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amalgamation</td>
<td>Unity of all knowledge</td>
<td>Unified process of scientific inquiry</td>
<td>Interdisciplinary Science</td>
<td>Interdisciplinary Science</td>
<td>Interdisciplinary Science</td>
</tr>
<tr>
<td>Combination</td>
<td></td>
<td>Unity of the conceptual structures of Science</td>
<td>Interdisciplinary Science</td>
<td>Interdisciplinary Science</td>
<td>Interdisciplinary Science</td>
</tr>
<tr>
<td>Coordination</td>
<td></td>
<td></td>
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</table>

### Table A1.2 Analysis of Aikenhead’s eight categories of STS in Blum’s categories.

<table>
<thead>
<tr>
<th>Intensity \ Scope</th>
<th>Within subject</th>
<th>Between Science subjects</th>
<th>Basic/applied Science and Technology</th>
<th>Science and Society</th>
<th>Science and the Humanities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amalgamation</td>
<td>8) STS content</td>
<td>5) Science through STS content</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combination</td>
<td>7) infusion of Science into STS content</td>
<td>6) Science along with STS content</td>
<td>4) Singular discovery through STS content</td>
<td>3) Purposeful infusion of STS content</td>
<td></td>
</tr>
<tr>
<td>Coordination</td>
<td></td>
<td></td>
<td></td>
<td>1) Motivation by STS content</td>
<td>2) Casual infusion by STS content</td>
</tr>
</tbody>
</table>
Table A1.3 Venville’s 16 cases of integrated Science education in Australia compared to Blum’s categories (Venville et al, 1998)\textsuperscript{24}.

<table>
<thead>
<tr>
<th>Intensity \ Scope</th>
<th>Within subject</th>
<th>Between Science subjects</th>
<th>Basic / applied Science and Technology</th>
<th>Science and Society</th>
<th>Science and the Humanities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amalgamation</td>
<td>1) School specialist approach*</td>
<td>3) Competitions * 4) Synchronized content and process*</td>
<td>10) Topic integration*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combination</td>
<td>2) Local community projects*</td>
<td>5) Thematic approach 6) Teaching approaches*</td>
<td>8) Technology based project*</td>
<td>11) Cross-curricular approach</td>
<td></td>
</tr>
<tr>
<td>Coordination</td>
<td>7) Integrated assignments*</td>
<td>9) Natural/informal integration*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{24} *= has been renamed or revised in Venville et al. (2007)