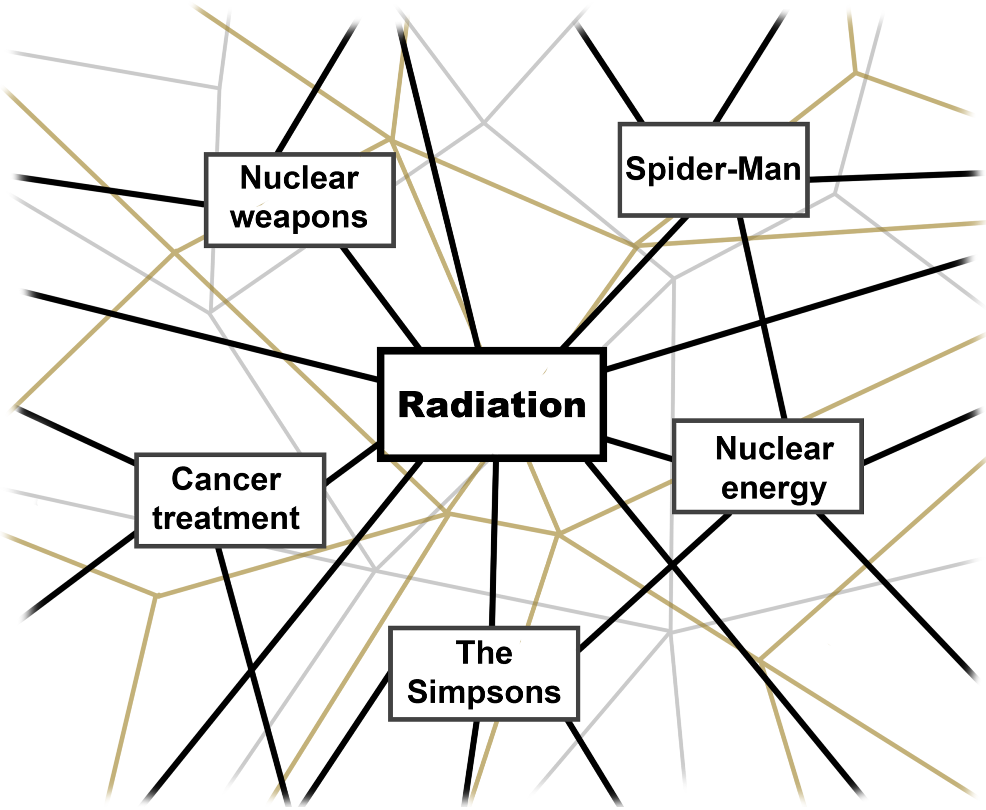
CHALMERS
UNIVERSITY OF TECHNOLOGY



How to bring the subject closer to the student

Developing a teacher guide to Vision II instruction

Kalle Svensson

DEPARTMENT OF COMMUNICATION AND LEARNING IN SCIENCE
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2024
www.chalmers.se

Master's thesis 2024

How to bring the subject closer to the student

Developing a teacher guide to Vision II instruction

KALLE SVENSSON

Department of Communication and Learning in Science
Chalmers University of Technology
Gothenburg, Sweden 2024

How to bring the subject closer to the student
Developing a teacher guide to Vision II instruction
KALLE SVENSSON

Supervisor: Tom Adawi, Department of Communication and Learning in Science
Co-supervisor: Eva Ask, Department of Communication and Learning in Science
Examiner: Philip Gerlee, Department of Mathematical Sciences

Master's Thesis 2024
Department of Communication and Learning in Science
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 (0)31 772 1000

Cover: A network symbolizing constructivist connections in a student's mind to the subject of radiation. Original work by the author.

Typeset in LaTeX
Printed by Chalmers Reproservice
Gothenburg, Sweden 2024

How to bring the subject closer to the student
Developing a teacher guide to Vision II instruction
KALLE SVENSSON
Department of Communication and Learning in Science
Chalmers University of Technology

Abstract

The 2019 TIMSS survey showed that a large share of Swedish year 8 students have negative attitudes towards science. Skolverket suggests that this could be counteracted by the use of a *scientific literacy* perspective in instruction, a perspective stating that general science education should educate students for everyday life rather than specific scientific careers. Surveys have shown that this is a perspective that few teachers seem to embrace fully. Other sources suggest that demonstration and laboratory work could be used to improve student attitudes towards science. This thesis develops a guide aimed towards science teachers, that guides in scientific literacy and its application, and argues for, and encourages the use of, demonstrations and experiments to improve student attitudes towards science. The use of scientific literacy as a basis for instruction is argued for from the perspectives of the current curriculum Gy11, science use in everyday life, democratic values, cognitive theories for learning and instruction, and the interest and motivation of students. The guide encourages connecting science to relevant societal concepts and popular culture where science is an integral part. Possible connections are exemplified through the subject of *radiation* in the course Physics 1a. The guide promotes a scientific literacy perspective in science education and is hoped to lay the groundwork for improved student attitudes towards science. Additionally, the scientific literacy approach is argued to ease understanding, aid retention, and help students understand the world they inhabit. From an ethical perspective, this approach has an inherent benefit to students' ability to understand societal questions, and in turn their ability to participate in democratic decisions as well-informed citizens.

Keywords: scientific literacy, visions, demonstration, teacher guide, radiation, societal connections.

Acknowledgements

I would like to express great gratitude to my supervisors, Tom Adawi and Eva Ask at Chalmers University of Technology, for their insightful guidance in the definition of this thesis, and in the realization of the same.

Kalle Svensson, Gothenburg, May 2024

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

Gy11	Curriculum of Swedish upper secondary school from 2011.
Gy25	Curriculum of Swedish upper secondary school from 2025.
STEM	The subjects of Science, Technology, Engineering and Mathematics.
TIMSS	Trends in International Mathematics and Science Study.

Contents

List of Figures

List of Tables

1

Introduction

1.1 Background

A large share of Swedish year 8 students have negative attitudes towards science, and this share is increasing over time (Skolverket, 2020). TIMSS is an international survey that monitors trends in student attitudes and achievements in mathematics, science, and reading. The survey is conducted every four years, and the latest survey of which the results have been published was conducted in 2019. This survey showed that 30%, 42% and 37% of students had negative attitudes towards biology, physics, and chemistry respectively. The survey also showed great declines in attitudes between year 4 and year 8 students.

To counteract these negative attitudes, *Skolverket*, the Swedish educational authority for the primary and secondary school levels, states in their text *Att se helheter i undervisningen*, that science teachers have the important task to "create meaningful teaching situations where the students have the opportunity to relate science phenomena to their own everyday life and to different areas that interest them" (Nilsson, 2012, p. 25), and they connect this to the concept of *scientific literacy* and *visions* within curriculum. Several researchers, such as Aikenhead (1996), argue that students often see science as a subject that is partly or entirely disconnected from their world.

Roberts (2007) defines two competing visions for the design of education curricula. These are parts of the broader concept of scientific literacy, representing the individual's ability to use scientific knowledge in everyday life. There is vision I, aiming to educate students to be the scientists and practitioners of tomorrow through the teaching of concepts, theories, laws and processes, and there is vision II, aiming to educate students to become enlightened members of society by connecting science to the world around them. The two visions can be understood as two extremes on a continuum, and both viewpoints may be needed in any one curriculum. In Sweden, the two visions have often been seen as competing agendas (Haglund & Hultén, 2017), where vision II competes against the traditionally used vision I in the development of new curricula.

Skolverket is responsible for setting the curricula for all courses up to and including upper secondary school. In the modern curriculum for the first physics course in the upper secondary school *Gy11* (Skolverket, 2011), some parts align with vision II, e.g. that the student should have the opportunity to develop “knowledge of the importance of physics for the individual and society,” or the core content; “views on societal questions based on explanatory models of physics, e.g. questions about sustainable development.” There is also the fact that the curriculum is stated in such a way that it is vague enough that educators can decide themselves how they want to teach, and to some degree how much they want to teach of every subject, which opens up the possibility for the individual teacher to take a vision II approach (Skolverket, n.d.). Returning to the text *Att se helheter i undervisningen* by Skolverket (Nilsson, 2012), there is a stated wish and encouragement for teachers to take such an approach, as well as acknowledgements of the tradition of teaching within vision I, the negative effect this has had on students’ interest in the STEM subjects and how teaching aligned with vision II might remedy this.

It is emphasised by Roberts (2007) himself that curriculum development projects often fall back to vision I, even when intentions may lie within vision II, as curriculum committees historically have been composed primarily by academic scientists, as is suggested to have been the case with the Swedish curriculum *Lpo94* (Haglund & Hultén, 2017). Further, Roberts (2011) acknowledges that there are discrepancies in how subject teachers receive vision I and II curricula, as teachers are typically more familiar with the vision I perspective through their own higher education. Engström and Carlhed (2014) conducted a study where they performed a cluster analysis on the survey responses of 268 Swedish upper secondary physics teachers in the academic year 2008-2009. They concluded that only 14% of teachers were part of the group that could be argued to fully embrace vision II, while 39% of teachers regularly connected physics to technology signifying a small and incomplete step into vision II, and that 46% of teachers are stuck in traditional teaching within vision I. Engström and Carlhed (2014) makes the following statement in their conclusion:

> Not every student in the Physics A course in secondary school in Sweden will complete higher education in the physics or energy domain, but all of them will meet notions and relations in the course that they are expected to understand and use to describe the world. Secondary school physics should incorporate physics teaching for citizenship and at the same time foster competence for those who want to seek higher education in physics. (s. 722)

This quote may serve as an example of what science teachers should strive for, from the perspective of these two educational researchers. From an educational perspective, one may also argue for the use of vision II along *constructivistic* learning models such as the model of *scaffolding* constructed by Bruner (1960) and *associative learning* constructed by Hebb (2002), by putting the subject in broader contexts of which students may already be somewhat knowledgeable.

Tackling the question of why year 8 students’ attitudes towards science are low, Lindahl (2003) showed that students considered experiments and demonstrations to be what makes science fun and interesting. She argues that students’ attitudes towards science are better when they are young, because when they are young they encounter science within fun theme days and exciting experiments, rendering the later, more theoretical part of school abstract, dull and boring in comparison. There are suggested advantages of using experiments in instruction to strengthen the motivation and interest of the students (Freedman, 1997; Lindahl, 2003), and the same benefits also exist with science demonstrations (Abrahams & Millar, 2008). McCrory (2021) likens demonstrations to theatre, describing the possibility of science demonstration to spark the students' interest.

> Like theatre, demonstrations have enormous potential to – create and sustain interest; stimulate curiosity; communicate and share emotions; reveal phenomena by showing, not just telling; direct focus; and to provoke further interaction, thought and discussion. (McCrory, 2021, Summary section)

Radiation physics, where abstraction is arguably high, will be used as an example extensively in this work. In the subject of radiation, one might use simple cloud chambers (Yoshinaga et al., 2014) in either demonstration, student experimentation or some blend of the two (from here simply referred to as "demonstration" in any case) to spark the student's interest. In cloud chambers, tracks of condensation make the path of ionizing radiation visible to the naked eye (Snowden, 2013), bringing what was invisible into the world of the students, along with a possible "wow"-factor.

Expanding on demonstrations like this, while returning to Robert's vision II, one may see beyond the didactic and educational-philosophical possibilities of a vision II-aligned teaching style, and find societal and democratic benefits in the understanding of the actual science and the connection of the subject to society at large. For instance, to counteract common misconceptions. In the case of radiation one could counteract the general discrepancy between radiological risk perceptions of experts and the general population (Perko, 2014), the specific undervaluing of the risk of Radon in buildings and the unnecessary stigmatization of areas, people, and objects exposed or possibly exposed to some level of radiation (Slovic, 2012). Democratic benefits could arise in that students develop a better understanding of political issues where radiation plays an important part, such as questions about nuclear power, long-term storage of radioactive waste and nuclear weapons.

With all these arguments for implementing vision II, why do only 14% of physics teachers embrace this perspective? Returning once again to *Att se helheter i undervisningen* (Nilsson, 2012), Skolverket argue that educational research does not generally answer questions that directly apply to the everyday work of teachers, rendering research to be regarded by teachers as separated from classroom work. Further, Skolverket refers to the work of Bransford et al. (1999), where the authors state that the language differences between teachers and researchers, and the already full schedules of teachers, hinder the teachers from assimilating new research/knowledge, which explains why many teachers express that research is at large irrelevant to their work. Therefore, the low application rate of the vision II perspective may simply be because teachers have generally not been in extensive contact with the perspective.

1.2 Aim

This thesis aim to develop an accessible guide for all science teachers, that guides in and promotes the connection of the science subjects to the world of the students, embracing the perspective of Roberts' vision II and the broader concept of scientific literacy to make the subjects more relevant for the students. The guide will use the subject of radioactivity within the course *Physics 1a* in the Swedish upper secondary school as a concrete example of application and connection. Science demonstration exemplified through the use of cloud chambers will serve as another part of making the subject more tangible, familiar, and interesting to the students.

The guide will be written entirely in Swedish and will follow the Swedish curriculum, as it is aimed towards the Swedish school.

1.3 Delimitations

This thesis does not:

- evaluate the resulting educational material empirically.
- discuss didactic choices in the educational material that do not involve vision II or closely related concepts.
- consider the future changes of the curriculum that may come with the new curriculum *Gy25*.
- discuss the current ways in which the subject at hand is taught.
- treat the resulting material as a final product that cannot or should not be changed, as the curriculum emphasizes that each teacher should make their own decisions in what is taught and how.
- try to create an "optimal" educational material, as that is deemed either impossible to do, evaluate or fit into the scope of this thesis.
- expand the concept of visions with the proposed, by others than Roberts, vision III, which is suggested to expand vision II with non-euro-centric science traditions (Aikenhead, 2007).

2

Theory

In this chapter, theory is presented under the three categories *Learning Science*, *Physics* and *Governmental Documents*. From a teacher's perspective, the physics category treats the content to be taught, the learning science category treats the method of teaching, and the category of governmental documents steers the teacher's decisions. From the perspective of the teacher guide, the learning science and governmental documents categories shape the guide, while the physics category serves as background to the provided examples in radiation physics.

2.1 Learning Science

2.1.1 Seven Emphases

Education curricula are designed from some form of basic thought of what, how, and why something should be taught (Roberts, 1982). An approach to categorize the diversity of ways of answering those questions is the *curriculum emphases approach,* where a curriculum emphasis is defined as a "coherent set of messages about science". Roberts (1982) defines seven emphases, which he argues to be exhaustive in what had been tried at the time. However, he also stated that he thought that other emphases were theoretically possible. The emphases should not be seen as mutually exclusive, but as broad orientations that science education can take. These emphases can also be seen as answers to students asking "why am I learning this?"

The "everyday coping" emphasis: As the name suggests, this emphasis states that science is an important means to understand and control one's environment, either natural or technological. The material processes scientific content which the student will meet in their everyday lives.

The "structure of science" emphasis: This emphasis treats how science as a subject grows and develops. Through repeated discussions of e.g. the interplay of evidence and theory, or models and their adequacy to explain certain phenomena, the science subject is expanded.

The "science, technology, and decisions" emphasis: This emphasis concentrates on the limitations of science and technology in handling practical affairs, either private or public. Science is distinguished from technology, and practical problems are clearly distinguished from scientific problems, the first demanding a defensible decision and the other warrants new scientific knowledge.

The "scientific skill development" emphasis: In this emphasis, the goal is not to accumulate knowledge, but to gain competence in the scientific process and what it entails.

The "correct explanation" emphasis: The products of science are unquestionably correct, and scientific knowledge constitutes a collection of facts that the student should learn without doubts of whether it is correct or not. The common notion of "master now, question later" is part of this emphasis.

The "self as explainer" emphasis: This emphasis communicates science as a cultural institution and its place in history, being driven by and driving human development alongside other systems of explanation such as religion and magic.

The "solid foundation" emphasis: The science being taught now is preparation for later studies to be commenced in the next level of the school system, and that is to be communicated to the students. What is taught in elementary school is to prepare for secondary school, which in turn should prepare for a future, less defined purpose, e.g. studies at a university. Seldom known is to what ultimate set of goals prior instruction should be directed towards.

2.1.2 Scientific Literacy

Scientific literacy is a broad and ill-defined concept of what "knowing science" means, most often in the context of competence and usage in society and one's own life (Roberts, 2007). Roberts (2007) authored the chapter *Scientific Literacy* in the first edition of *Handbook of research in science education*. A history of authors defining scientific literacy in different ways has resulted in an absence of a consensus on what the exact definition should be, to such a degree that Roberts in the afterword of the chapter quotes the character Humpty Dumpty from Lewis Carrol's *Through the Looking Glass*, when discussing the varying definitions of different authors. "When I use a word, it means just what *I* choose it to mean—neither more nor less." However, there is an argument that the term may be context-dependent, which may render the goal of a common definition not worth chasing. George DeBoer (DeBoer, 2000) makes the following comment about scientific literacy, which will serve as a broad definition of the term.

> The one specific thing we can conclude is that scientific literacy has usually implied a broad and functional understanding of science for general education purposes and not preparation for specific scientific and technical careers. (p. 594)

Roberts (1982) defines two visions within the scope of scientific literacy that represent two extremes on a continuum.

> Vision I gives meaning to SL [scientific literacy] by looking inward at the

> canon of orthodox natural science, that is, the products and processes of science itself. At the extreme, this approach envisions literacy (or, perhaps, thorough knowledgeability) within science. [...] Against that, Vision II derives its meaning from the character of situations with a scientific component, situations that students are likely to encounter as citizens. At the extreme, this vision can be called literacy (again, read thorough knowledgeability) about science-related situations in which considerations other than science have an important place at the table. (p. 730)

Here, Roberts gives another definition of scientific literacy, which describes it as having "thorough knowledgeability" within science and/or related matter. Looking back at the seven emphases that Roberts (1982) defined, he argues that vision I incorporate the "scientific skill development" and the "structure of science" emphases, while vision II partakes in those as well, along with incorporating three more, "everyday coping," "science, technology, and decisions," and "self as explainer". "Solid foundation" and "correct explanation" are argued to be largely historical and not part of the present discussion on curriculum. This indicates that vision II is an extension of vision I, rather than an entirely different perspective, and Roberts (2007) pointed out that "Vision II subsumes Vision I, but the converse is not necessarily so" (p. 768).

Scientific literacy has close connections to the concept of *bildung*, which is a philosophical-educational tradition in Central and Northern Europe that in general promotes personal development and/or development towards democratic citizenry (Sjöström & Eilks, 2018). The Swedish tradition of "folkbildning" emphasizes that children should be educated to become responsible actors in society. The term "allmänbildning," is the Swedish translation of the German word "allgemeinbildung," and emphasizes personal knowledge and competence in all human capacities.

2.1.3 The Integrated Classroom/Curriculum

In the realm of *integrated classroom/curriculum*, the standard *disciplinary perspective* (staying within the boundaries of the discipline) of traditional education is contrasted by the *integrated perspective* that advocates interdisciplinary education when applicable to the subject at hand (Rennie et al., 2011). One argument for this integrated perspective is that it enables learners to face subjects through the lens of interdisciplinary issues that may be more relevant and motivating to them, as the multiple dimensions and interdisciplinary nature of the issues better reflect the realities of the world outside school and the experience of the learners. However, it is emphasized that there needs to be a balance between the disciplinary and integrated perspective in what is taught, as students need both disciplinary knowledge and a wide understanding of the issues that shape their lives, as illustrated by the following excerpt from Rennie et al. (2011).

> Within a balanced curriculum, students can be encouraged to reflect on and critique subject-specific knowledge, understand the limitations of that knowl-

> edge, particularly in applied situations, and recognize when creativity, lateral thinking, adaptive help-seeking, and trial and error play a role in the knowledge-building process. This broader, more balanced view of curriculum allows students, teachers, and researchers to value disciplinary knowledge and to utilize the cognitive and practical tools that the discipline may offer. At the same time, it allows students, teachers, and researchers to look outward in order to engage in relevant, exciting, and motivating real-world problems and issues, and to explore how disciplinary knowledge can be useful in understanding, addressing, and solving those problems and issues. Moreover, it allows students and teachers to realize the limitations of disciplinary knowledge in specific contexts and to explore other avenues and sources of knowledge that may be more practical, expedient, informative, or simply more social or fun, than allowed by the rigorous rules and rigid processes of the discipline. (p. 157-158)

2.1.4 Experiential Learning

Experiential Learning is the learning that originates from the experience of actions and sensations of the real world, and not just ordinary classroom instruction (Kolb, 1984). Within the realm of experiential learning reside learning models such as Dewey's *learning by doing* and Piaget's *four stages of development*, but also ideas of learning from pure perceptions of the world as it plays out with or without interaction. Kolb (1984) defines the experiential learning cycle as four stages that the learner must go through again and again to learn from experience. These are

- *Concrete Experience:* where the learners involve themselves fully and without bias in the new experience,
- *Reflective Observation:* where they observe and reflect on their experience from many perspectives,
- *Abstract Conceptualisation:* where they must transform what they have observed into logically sound concepts and theories,
- *Active Experimentation:* where they must use these theories and concepts to make decisions and solve problems.

Since all people learn from experience in their everyday lives, this is argued to be a natural way to learn.

2.1.5 Variation Theory

In variation theory, it is argued that concepts are learned by discerning them from other concepts by examining their *critical aspects* and their corresponding *critical features*, and evaluating how they differ from other concepts (Lo, 2012). The concept to be learned is called the *object of learning* and the critical features of this object are the features that define that object. Without those features, it would not be the same object. The critical aspects, on the other hand, are in what dimensions the critical features reside. If the object of learning is a red ball, which would not be the same if it were black, the redness is a critical feature of the object, and therefore colour is a critical aspect of the same object.

Variation theory states that students learn concepts by differentiating them from other concepts through the use of variation. The teacher defines the critical features of the object of learning and shows how the concept at hand is no longer the same if those critical features are varied within the dimension that is the critical aspect. By pointing at a red ball and calling it “red” a young student cannot conclude if “red” refers to the colour, shape, or another feature of the ball, but by then pointing to other red things, e.g. a sofa or a toy, and saying “red” the student may understand that the overarching theme is the colour red. One may also vary such things that are not a critical aspect, and thus show how the concept stays the same.

2.1.6 Cognitivism and Meaningful Learning

Cognitivism is a collection of learning theories that build on the idea that learning happens when information is processed in the mind, forming relationships between different pieces of information and experiences to build a new, more complete picture (Bates, 2023). One such theory is Ausubel’s *meaningful learning*, which says that effective learning occurs when students can link new information with previous experiences to form new understanding (Bryce & Blown, 2023). From a teacher’s perspective, several implications arise with this line of thought. Teachers must conclude what the individual students already know, what they do not know, and what they have got wrong. Students may develop a naive and wrong understanding of scientific issues based on their everyday experiences. Additionally, as students are increasingly subjected to incorrect and non-scientific information on the internet and social media, students may have a worse starting point for learning than if they were entirely new to the subject. This is made worse by neuroscientific results that suggest that new, better understanding does not replace old, incorrect understanding, but merely suppresses it, leaving it available for cross-reference and further misunderstandings (Gordon et al., 2019). However, this comes together quite well with the theory of another cognitivist author, Bruner, and his theory of *scaffolding* that describes learning as the building of physical scaffolding, adding new understanding and knowledge to the already existing scaffolding below to form a new greater picture of understanding and knowledge (Bryce & Blown, 2023). In this view, teachers should not and need not try to remove these old structures of misunderstanding, as these are structures that students may support much of their correct knowledge on, and on which further knowledge may be built.

2.1.7 Associative Learning

The theory of associative learning is a cornerstone of educational neuroscience (Bates, 2023) and was formulated by Hebb (2002) to explain what happens when neurons in the brain are repeatedly activated alongside each other. He claimed that the activation form links (i.e. synapses) between the activated regions, and thus form an association between them. This leads to conclusions in line with those in the area of cognitivism, such that knowledge and understanding may be built on preceding knowledge and understanding. It may also be taken further, as the association does not necessarily depend on the connection of new and old knowledge within the same subject. Instead, the association may be made between most anything.

2.2 Physics

2.2.1 Function and History of the Cloud Chamber

The cloud chamber, also called the “Wilson chamber”, was invented in 1895 by Charles T.R. Wilson to research the process of droplet formation in clouds (Chaloner, 1997). This chamber worked by saturating the air with water and then quickly expanding the chamber’s volume with a piston so that the air became cooled and supersaturated, as colder air cannot hold as much water as warmer air. When this happens, droplets form by the disturbance caused by ionizing particles travelling through the air, leaving trails of droplets behind. This supersaturated state does not last for long until the extra water is condensed and everything has to be redone.

Although invented in 1895, it was not until 1911 that Wilson first discovered and photographed the tracks of condensed water vapour originating from the interaction between the supersaturated air and ionizing particles that passed through the air inside the chamber. This discovery led to intense development within the field of particle physics, and Wilson received a joint Nobel Prize in physics in 1927 for his invention. Another four Nobel Prizes in physics have been received for research made with cloud chambers, including the discovery of antiparticles.

Wilson’s cloud chamber design was further developed by letting a motor expand the air in the chamber several times a second, making the observations more continuous than when one had to expand it by hand, as was the case in the first design. Later, the expansion design was superseded by the *diffusion* cloud chamber, where the air was continuously supersaturated with alcohol by creating a temperature gradient in the chamber. The heated roof of the chamber warmed the air that was saturated with alcohol, which then fell to the cooled bottom of the chamber which cooled the air, making it supersaturated with alcohol.

In the 1950s the cloud chamber was largely superseded by the *bubble chamber*, where ionizing particles form bubble trails in a superheated liquid instead of forming droplets in supercooled air, which was the case with the cloud chamber (Martin & Shaw, 2019).

2.2.2 A Simple Cloud Chamber Design

Yoshinaga et al. (2014) designed a simple cloud chamber that does not require dry ice or any other hard-to-get and/or potentially hazardous cooled substance to operate. Instead, it only requires warm water and a mixture of water and table salt cooled by a common consumer freezer.

A metal tank is placed on the top of a transparent plastic vessel with a hole on the top, sealed with aluminium tape. Four stacked sheets of felt soaked with alcohol are attached under the aluminium tape. A base is made by putting a bag of salt mixture of 1 g salt per 2 ml of water between two aluminium plates, held together by two binder clips, and spaced with two pieces of foamed polystyrene.

Before use, the aluminium container is filled with water at 60 °C, and the baseplate with the bag of water-salt mixture is frozen in a freezer, reaching a typical negative 18-20 °C.

2.2.3 Radiation

The term radiation is a collective term for energetic (i.e. fast-moving) particles or waves (Martin & Shaw, 2019). Ionizing radiation is the sub-collection of electrically charged particles and electromagnetic waves that may take/knock away electrons from atoms, i.e. ionizing them. The most common set of ionizing radiation is *alpha*, *beta*, and *gamma* radiation. These kinds of radiation are emitted from atomic nuclei when they go from a high-energy state to a lower one, an occurrence which is referred to as a *decay*. Alpha radiation is essentially a Helium nucleus, two protons and two neutrons, without the usual electrons of the Helium atom. Alpha decay occurs when a large nucleus with at least 100 protons jumps to a lower overall energy state by emitting an alpha particle. Beta radiation originates either from the decay of a neutron into a proton, where an electron (beta particle) is emitted, or the decay of a proton to a neutron where a positron (the electron's anti-particle which is also a beta particle) is emitted. Again, these decays are jumps to lower energy states. When a large nucleus (many protons and neutrons) decays by alpha or beta decay, the remaining nucleus is often left in an excited state, i.e. the nucleus is not in its lowest possible energy state. Gamma radiation is highly energetic photons that are emitted from a nucleus that decay from such an excited state to the ground state, in much the same way as electrons in an atomic shell would release a photon when de-exciting from an excited state to the ground state, but with many times more energy/higher frequency. High-energy light stemming from electron decays, i.e. X-rays and ultraviolet light, is also ionizing, although to a lesser degree.

The addition and subtraction of protons and neutrons during alpha and beta decay results in the nucleus becoming another element than it was before. If this new element is stable, it will not decay any further. If it is not, it will decay again. When a nucleus decays is a matter of statistics. The most commonly used measures are the concepts of half-life and lifetime. Half-life is the time it takes for a sample of N nuclei of the same isotope to decay to the degree that only half of the original ($N/2$) isotope remains. Half-lives vary wildly between different types of nuclei and decays. Alpha decays have half-times ranging from nanoseconds to 10^{17} years, beta decays have half-times ranging between milliseconds and 10^{16} years, and the half-times for gamma-decays is about 10^{-12} seconds in any nuclei. The remaining nuclei in a sample after time t may be estimated for large N by the equation 2.1, where $\lambda = ln(2)/t_{1/2}$, and $t_{1/2}$ is the half-life of the nuclei.

$$N(t) = Ne^{-\lambda t} \tag{2.1}$$

The lifetime of a nucleus is equal to the half-life times the square root of two ($t_{lifetime} = \sqrt{2}t_{1/2}$) and is the statistical mean lifetime of a single nucleus.

The term *activity* refers to how often decays occur, i.e. some kind of radiation is emitted, in a sample of radioactive material with N nuclei. Activity is measured in *Becquerels* (Bq), which is defined as one decay per second. Activity A can be estimated for large N by the equation 2.2.

$$A = \lambda N \tag{2.2}$$

Because samples often contain very large numbers of nuclei, the *law of large numbers* says that equations 2.1 and 2.2 are generally very accurate.

Another common type of ionizing radiation is *muons* originating from the upper atmosphere. There, highly energetic particles, originating from sources in space, called *cosmic rays* slam into atmospheric molecules, resulting in fast-moving muons among many other kinds of particles. The muon is essentially a sibling to the electron, having the same charge but being about 200 times heavier. These muons race toward the earth's surface, where they get absorbed by the ground. Mouns hits the earth's surface at approximately one muon per square centimetre per minute.

Alpha particles, beta particles, gamma rays, and atmospheric muons can penetrate through solid materials to various degrees (Domenech, 2017). The depth of penetration varies with the energy of the radiation for each particle. Generally, alpha particles have the least penetration power and can be stopped by a piece of paper. Beta particles most often need more than a paper to be stopped, but do not come far in most materials. Gamma rays have more penetration power, requiring inches of dense material (such as lead) to be stopped. Atmospheric muons have even greater penetration power, and are known to penetrate hundreds of meters underground (Uretsky, 1997).

2.2.4 Sources of Radiation

There are many types of radioactive nuclei. Most of the known nuclei are radioactive, although most matter is not, as all radioactive matter decays until they have transformed into a stable element that will not decay any further, resulting in an accumulation of non-radioactive matter. In table 2.1, sources of radiation that are commonly used in schools (Strålsäkerhetscentralen, 2016) are listed along with their decay modes, highest energy radiation, and half-life (Nordling & Österman, 2020).

Most long-lived radioactive elements occur naturally in the environment. The radiation from these, along with the radiation resulting from cosmic rays, e.g. muons, makes up the *background radiation*. This radiation varies with the place on earth, e.g. because of different compositions of the bedrock (Jelinek & Eliasson, 2015).

Table 2.1

Commonly Used Sources of Radiation in Schools.

Nucleus	Decay	Energy (MeV)	Half-life (years)
Co-60	Beta + Gamma	0,31+1,3	5,27
Sr-90	Beta	0,546	28,80
Cs-137	Beta + Gamma	1,18 + 0,66	30,08
Ra-226	Alpha	4,78 + 0,19	1600
Am-241	Alpha + Gamma	5,49 + 0,060	432,6

Note. Values and decay modes taken from Nordling and Österman (2020), for radioactive nuclei listed by Strålsäkerhetscentralen (2016).

2.2.5 Radiation and Health

Radiation may pose a health risk in large quantities (Martin & Shaw, 2019). All radiation may release energy into the body, running the risk of hurting important tissues. Ionizing radiation poses the greatest risk, as it may ionize the molecules in the body. In the short run, the creation and accumulation of toxic chemicals inside the body pose the largest risk. The ionizing radiation may also hurt the DNA of the cells, which can lead to health complications e.g. cancer, in the long run, possibly decades after the exposure.

Beta radiation generally only affects the skin, as it cannot penetrate very deep into the body. Alpha radiation is easily stopped by the skin. However, if alpha-emitting isotopes get into the body, e.g. with breath or digestion, the radiation may cause considerable damage to sensitive organs. The same is true for beta- and gamma radiating nuclei too. As gamma radiation may penetrate through the whole body, gamma radiation from sources outside the body can damage vital internal organs.

To quantify the health risk/dosage of radiation, several measures and units are used. One measure is the total energy deposited per unit mass of tissue, with the unit *grays* (Gy) where $1\ Gy = 1\ J/kg$. Another measure that better measures the risk is the *sievert* (Sv) also defined as J/kg, but weighted according to several factors, such as the kind of radiation, which organs are exposed to the radiation, and the rate of deposition of energy. Figure 2.1 shows estimations of the radiation dosage for different activities in the weighted sieverts-unit (Munroe, n.d.).

2.2.6 Radiation in Society

2.2.6.1 Popular Culture

Radiation as a concept is prominent in popular culture. The University of Alabama at Birmingham (n.d.) have a project called *UAB Radiation Pop Culture Project* where they have listed around 1000 references to the field of radiation. In the realm of superhero media, there is an abundance of heroes and villains that have their origin in exposure to radioactivity. Prominent examples are *Spider-Man* who is bitten by a radioactive spider, *The Fantastic Four* who develop their powers from exposure to cosmic radiation received in space as astronauts, and the *Incredible Hulk* who is exposed to gamma radiation.

Another notable representation exists in the television series *The Simpsons* where a neglected nuclear power plant is the workplace of one of the main characters, where images of green, oozing radioactive waste and three-eyed fish are common along other less-than-correct representations of nuclear power (Office of Nuclear Energy, 2018).

The bombings of Hiroshima and Nagasaki scarred the population of Japan. The most famous representation of the collective trauma is that of *Godzilla*, the giant lizard-like creature that breathes radiation and whose fury is awoken by American testing of nuclear bombs in the Pacific Ocean (Anisfield, 1995). Godzilla serves as a metaphor for the nuclear bomb, and its merciless and indiscriminate nature.

Yet another notable representation is within the television miniseries *Chernobyl*, where the story of the Chernobyl nuclear accident is retold with some creative liberty taken (Mazin & Renck, 2019).

2.2.6.2 Nuclear Weapons

Nuclear weapons harness the energy of nuclear decay to output vast amounts of energy simultaneously, which creates an explosive effect (Martin & Shaw, 2019). Besides the explosion itself, a vast amount of *fallout* consisting of material that did not decay during the blast and new materials resulting from the decay chains in the nuclear reaction are released into the atmosphere, eventually falling on the surrounding area.

Two nuclear bombs have been used in war, one each over the Japanese cities Nagasaki and Hiroshima, during the last days of the Second World War (Colombia Center for Nuclear Studies, 2012). These bombings resulted in the deaths of 90,000 to 166,000 people in Hiroshima, and another 60,000 to 80,000 in Nagasaki in the first months, counting the deaths from the explosions and their resulting heat, as well as the deaths by acute radiation poisoning. The survivors ran a 46% greater risk of developing leukaemia and a 10.7% greater risk of developing non-leukaemia cancers than the non-affected population. Many thought that the cities would become nuclear wastelands in the wake of the bombings, but these worries never materialized. Already in the spring of 1946, not even a year after the bombings, the remaining citizens of Hiroshima were surprised to find their city dotted by the Oleander flower. The flower, now the official flower of Hiroshima, served as the first sign of their city's ability to regenerate after the bombing. The radioactivity originating from the bombings is today so low that it can barely be distinguished from the background radiation.

More than 500 atmospheric nuclear weapons tests were conducted in the years between the invention of the nuclear bomb and an agreement to abolish atmospheric tests in 1963 (Centers for Disease Control and Prevention, 2014). These tests dispersed radioactive materials and gases into the atmosphere. Heavy materials fell to the ground in the vicinity of the test sites, but lighter particles and gases could travel far. The US Centers for Disease Control and Prevention estimates that all Americans born after 1951 have received some exposure to radioactive fallout, and that this might have resulted in a slightly increased risk of developing cancer. In Sweden, small amounts of radioactive materials from nuclear blasts remain in nature and continue to affect the Swedish population (Andersson et al., 2007).

2.2.6.3 Nuclear Power

Nuclear Power is the collective name for technologies that harness the power of nuclear decay through a controlled nuclear reaction (Martin & Shaw, 2019). All large power plants use a process called *fission*, where the rate of the reaction is heightened but not accelerating, unlike in a nuclear weapon where the reaction accelerates at a very high speed. The energy from the decay is used to warm water, which turns into steam, which in turn drives a turbine that creates electricity.

Accidents in nuclear facilities may lead to the emission of radioactive material into the surroundings. The two accidents of the greatest scale were the accidents at the nuclear power plants in Chernobyl in 1986, caused by design issues in combination with poor safety culture, and Fukushima in 2011, caused by damage to the facility by an earthquake and a following tsunami (Ritchie, 2017). The number of deaths attributable to the radiation emissions from the accident at Chernobyl is disputed, but the confirmed deaths are less than one hundred. Although, the uncertainty is large, and the true number might be several hundreds. Only one death have been confirmed due to the accident at Fukushima. This was a worker at the power plant that later developed lung cancer due to exposure to radiation after the accident. However, there appears to be no or very low increased risk of radiation-related health issues in the overall population. Other health issues stemmed from the actions taken around the accidents. One of the greatest public health issues in these accidents was mental health problems stemming from the uprooting of people who had to evacuate, and the thinking that one's health might have been affected by the accident, as well as the stigmatization of those who were affected (Ohba et al., 2021). During the evacuation of the area surrounding the power plant in Fukushima, more than 60 people who were evacuated from hospitals and nursing homes died during or soon after the evacuation, and even more died due to stress in the following months, rendering the evacuation itself the deadliest part of the Fukushima accident.

Nuclear power plants continuously create nuclear waste in the form of spent fuel and material contaminated by the fuel (Strålsäkerhetsmyndigheten, 2024). For now, this waste cannot be economically disposed of in any safe way besides storage, which is complicated as the fuel often consists of materials that have high activity and very long life spans. In Sweden, most nuclear waste is stored at intermediate storage at the nuclear facilities in Oskarshamn, waiting to be stored long term in a not-yet functioning long-term storage in the bedrock, plagued by fears that radioactive materials may leak into the groundwater.

2.2.6.4 Radon

Radon is a heavy and radioactive noble gas that originates from the decay chain of Uranium (Grzywa-Celińska et al., 2020), and itself decays into radioactive elements that radiate further. The gas emancipates into the air from the earth's crust as the gas finds its way through cracks and fissures in the bedrock from which the gas originates. Besides leaking from the ground directly, Radon also dissolves in the groundwater, which then releases it slowly into the air when brought to the surface. The gas is generally only present in very low concentrations in the open air, but it may accumulate inside structures, buildings and homes, resulting in high concentrations that, when taking into account the prolonged presence of people, constitute a considerable health risk. Approximately 40% of the radiation to which humans are exposed comes from Radon, and the gas is responsible for 8% of lung cancer deaths in the EU. The health risk posed by Radon is primarily when inhaled, as the alpha radiation cannot penetrate the skin of the body. Ingestion of Radon-contaminated food or water is not considered to pose a significant health risk.

Radon can also originate from buildings themselves as the materials used, mainly concrete, are made of rock and may therefore contain Uranium, which again leads to the emission of Radon (Jelinek & Eliasson, 2015). Radon is odourless and colourless, which makes measurement the only way to detect its presence (Strålsäkerhetsmyndigheten, 2022). This also means that people cannot know if they live in the presence of Radon in concentrations above the recommended limits. The Swedish Radiation Safety Authority estimates that 400,000 Swedish homes have Radon levels above their limit for what is acceptable. A study conducted in the 1980s in an area of New Jersey characterized by very high Radon levels in many homes showed that the residents were essentially apathetic to the posed risk (Sandman et al., 1987). Few had made any measurements, believing that the problem did not apply to their own home.

2.2.6.5 Medical Use

Ionizing radiation is used for medical purposes (Martin & Shaw, 2019), where imaging and radiation therapy are two common usages. In one common type of imaging, X-rays are sent through the body of interest, where the X-rays are absorbed to a different degree depending on material density. The remaining X-rays are collected, and an image is created showing the differing densities of the materials in the body of interest, e.g. bones and tissue. In radiation therapy, concentrated beams of ionizing radiation are used to deposit energy into cancerous tumours with the intent of killing them. Electrons and photons are most commonly used, but protons are used as well, and there is research in using light nuclei such as Helium and Carbon.

2.2.6.6 Experts vs. the General Population

The general population often perceive the risks of radiation differently than experts (Slovic, 2012). In comparison to experts, the general population seem to value the risks of nuclear power and nuclear waste storage too high and the risks of medical X-rays and Radon too low. This is reason to believe that the public is ill-informed of the actual risks of radiation. Events like the ones at the nuclear power plants Chernobyl and Fukushima, and the dropping of nuclear bombs over Hiroshima and Nagasaki, have created a bad image of radiation as a topic. Surveys conducted on the American population before and after the initial events at Fukushima, where the subjects were asked what was the first thing that comes to their mind when thinking about “nuclear power”, showed that words like “disaster” and “bad” came up far more frequently after the accident than before (Leiserowitz et al., 2011). A global decline in support for building more nuclear power plants further reinforced the notion that the public image of nuclear power had worsened. Yet, it is to be said, and experts do, that the use of coal power, a substitute for nuclear power, causes much greater premature death than nuclear power, which still generates far more concern in the general population (Slovic, 2012). This big concern shows again in the estimate that some radiation emission standards cost 100 million dollars or more (in 1995 dollars) per year of life saved, which can be compared to the laws mandating seat belts estimated to cost 69 dollars per year of life saved (Tengs et al., 1995).

This perception/bad image, of radiation can result in less-than-desirable outcomes. In 1987, two men searching for metal scrap in Goiania, Brazil, sawed open an abandoned cancer therapy device and found a 28-gram piece of highly radioactive material. The glowing material attracted workers and children who began playing with it, and before the danger was realized several hundred people had been contaminated by the material and four people eventually died of acute radiation sickness (Petterson, 1988). Publicity of the accident led to a stigmatization of the whole region and the prices of products from the region fell by 40%, risking the livelihoods of the residents, even though nothing was ever found to be contaminated. The situation is similar in the Fukushima region, as consumers avoid its products despite products showing no sign of contamination. An analytical model suggests that regional stigmatization could be the main cost to society in the case of a hypothetical detonation of a radiological dispersal device, i.e. a great emission of radiation (Giesecke et al., 2012).

2.2.7 Safety in Laboratory Work and General Radiation Safety

According to the Swedish Radiation Safety Authority, there is no need to take extra precautions beyond thinking things through and planning well when working with radiation sources allowed in schools (Strålsäkerhetsmyndigheten, 2018). However, they do list that this would include things like:

- Never drink, eat, or smoke in the laboratory where you work.
- Keep distance to the radioactive material.
- Always use protective gloves and glasses when handling radioactive materials, and change gloves before touching other things.
- Do not touch your face or hair during work.

- Wash your hands before transitioning to other work or leaving the laboratory.
- Regularly making contamination measurements on surfaces that might have come in contact with the radioactive elements.
- Follow the instructions that apply to the workplace.

2.3 Governmental Documents

2.3.1 Swedish Curriculum in Upper Secondary School Physics

The curriculum for the Swedish upper secondary school sets up five “aims of the subject” for the courses in physics, which are cited below (Skolverket, 2011).

1. Knowledge of the concepts, models, theories, and working methods of physics, and also understanding their development.
2. The ability to analyse, and find answers to subject-related questions, and to identify, formulate and solve problems. The ability to reflect on and assess chosen strategies, methods, and results.
3. The ability to plan, carry out, interpret, and report experiments and observations, and also the ability to handle materials and equipment.
4. Knowledge of the importance of physics for the individual and society.
5. The ability to use a knowledge of physics to communicate, and also to examine and use information.

The core content of the course *Physics 1a* is mostly subject-related, although some topics have a clear vision II orientation. These are:

- energy resources and use of energy for a sustainable society,
- views on societal questions based on explanatory models of physics, e.g. questions about sustainable development.

The core content category “Radiation in medicine and technology” which is of extra interest in this thesis, contains the following points;

- Radioactive disintegration, ionizing radiation, particle radiation, half-life, and activity.
- Orientation to electromagnetic radiation and the particle properties of light.
- The interaction between different types of radiation and biological systems, absorbed and equivalent doses. Radiation safety.
- Applications in medicine and technology.

The course is part of the overall curriculum *Gy11* (Skolverket, 2011) where the word "democracy" occurs 13 times in different forms, stating among else the importance of transferring democratic values to the students and giving them sound foundations to participate in the democratic society.

2.3.2 Scientific Literacy and Socio-Scientific Issues

Skolverket's publication "Att se helheter i undervisningen" (Nilsson, 2012) is a compilation of scientific research about teaching STEM. In this publication, Skolverket refers extensively to scientific literacy and Roberts' vision I and II. Skolverket makes the following statement (freely translated by the author) about the traditional curricular approach.

> Traditionally, the school's science education has focused on a vision I approach to science knowledge, which is considered by many researchers to have led to a reduced interest in science among students. (p. 20)

A suggested remedy to this is said to be the use of vision II and to skew the instruction more towards a scientific literacy approach. Skolverket refers to a model of what defines a scientifically literate person, which states that a scientifically literate person is one who

- is interested in and understands the world around them,
- engages in communication about and in natural sciences,
- can identify questions, investigate and make evidence-based conclusions,
- is sceptical about and questioning others' natural sciences claims,
- make well-founded stances about their surroundings and their health and well-being.

To help students develop these capabilities, it is argued within the text that connecting STEM learning to socio-scientific issues is the fundamental way of doing this. Socio-scientific issues are defined as societal challenges which have both scientific and social dimensions, e.g. pollution, genome-editing and climate change. References are made to research, including that of Rennie et al. (2011), that shows that students develop more positive attitudes, increased motivation, and increased ability to apply scientific knowledge in larger contexts when instructed through a socio-scientific framework. Although it is emphasized that both visions must have their place in the curriculum, students must both know the science and its influence on themselves and society.

2.3.3 Laws on Radioactive Materials in School

Swedish schools in the upper secondary level have the right to use radiation sources in their instruction if they meet the requirements for handling those set by the

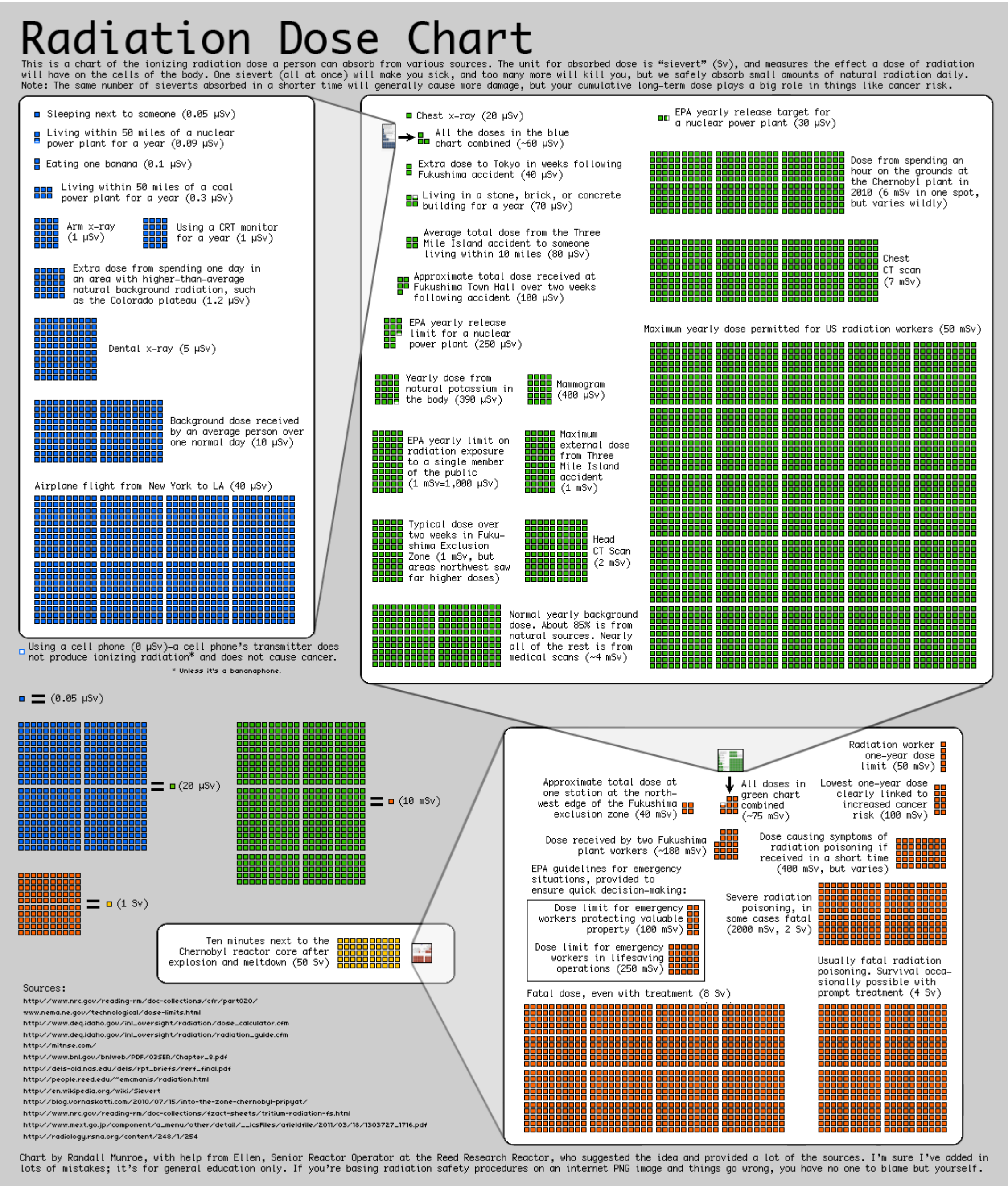
Swedish Radiation Safety Authority (Yngvesson, 2018). The sources themselves must have an activity limited in such a way that

1. the total activity of alpha decaying nuclei does not exceed 50 kBq,
2. the dose equivalent at a distance of 100 mm from the source of beta decaying nuclei do not exceed 50 µSv per hour,
3. the dose equivalent at a distance of 100 mm from the source of gamma decaying nuclei does not exceed 10 µSv per hour.

In upper secondary school, students may handle radiation sources in laboratory instruction under the teacher's supervision, while in lower levels of school, radiation sources may only be handled by teachers for demonstration purposes.

Figure 2.1

Infographic on Dose Equivalence



Note. Original work by XKCD (Munroe, n.d.) .

3

Methods

This chapter presents the choices made in the design of the teacher guide, as well as the reasoning behind those choices. The presentation begins with the aims of the guide, then leads on to the framework from which it operates, and the arguments behind the choice of content.

3.1 Aims and Content

The aim of the guide has two parts. Firstly, there is the overall and indirect aim of the guide to improve students' attitudes towards science. Secondly, there is the specific and direct aim of the guide to inspire, encourage, and help teachers in the application of vision II instruction, and encourage the use of demonstrations as a tool for nursing students' interest and motivation.

The guide introduces scientific literacy and Robert's visions and emphases, and explains why the vision II perspective should be encouraged. This is broken down into the main curricular and didactic arguments. To encourage the use of demonstrations, the guide calls attention to the effects of demonstration on students' engagement and attitudes, and what this does to student learning. Examples are used to guide the application of these concepts and ideas, showing their real-world use. The subject of radiation in the course Physics 1a was chosen to exemplify the application in both activity and the design of the plan for the greater subject area, as this subject is largely theoretical in its perceived impact on students' lives while being a non-trivial part of the real world around them (Skolinspektionen, 2018). However, this could probably be said about most other science subjects too, since science as a whole tends to be seen as disconnected from the students' world, as argued by Aikenhead (1996).

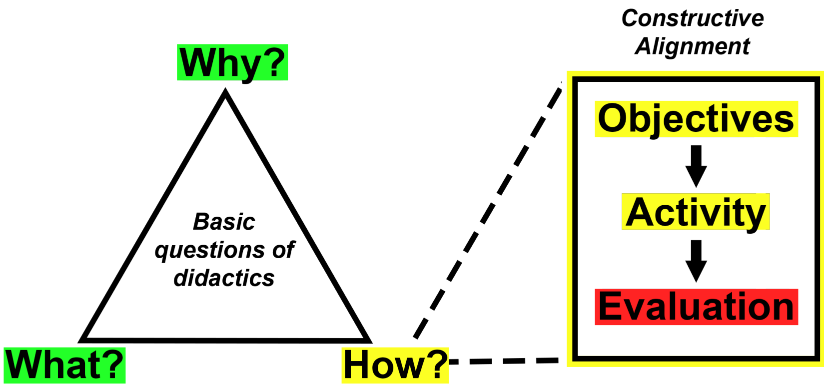
The use and impact of the guide probably depends on how accessible it is. To make the guide accessible, emphasis is put into not making the guide overly long or overly theoretical, while not excluding content important to the aim of the guide.

3.2 Framework

The overall framework of the teacher guide is designed in the same way as the curriculum Gy11 (Skolverket, n.d.), guiding the teacher in the process of the design of the lesson plan rather than stating explicitly what and how things should be done. The concepts *constructive alignment* and *didactic teaching* are two philosophies in the design of education. Didactic teaching asks the questions: *what* should the students learn, *why* should they learn it, and *how* will they learn it? Constructive alignment on the other hand asks what *objectives* the student should meet, what *teaching* should meet these objectives, and what *assessment* is needed to check if the teaching has met the objectives. Combining these two philosophies, the teacher guide can be said to answer the questions *what* and *why*, as well as giving guidance to the teachers answering the question *how?* This last question *how* might be broken up and redefined with the philosophy of constructive alignment, where the assessment is left to the individual teacher while the material gives guidance to the design of the objectives and the activity. This is shown in the colour-coded Figure 3.1, where the guide answers green, yellow is given guidance and red is left out.

Figure 3.1

The Basic Questions of Didactics and Constructive Alignment Within This Work



Note. What the guide answers (green), gives guidance to (yellow), and does not give guidance to (red). The graphic is an original work by the author.

The omission of guidance for assessment is made because it is irrelevant to the aim of this thesis and its topics. It is also important to note that Skolverket states objectives at the curriculum level, which to some degree directs the objectives at the activity level.

From the perspective of Robert's emphases and visions, the five emphases constituting vision II, those being "scientific skill development", "structure of science," "everyday coping," "science, technology and decisions," and "self as explainer", form another framework which should permeate instruction. In this view, the student should learn science not only to lay the groundwork for possible scientific careers but also to understand the world they live in, the use of science and its limitations in decision-making, and to understand science as the human endeavour that science is.

One could argue, without being wrong, that the visions and scientific literacy in general is more of a philosophy at the curricular level rather than the activity level. In the teacher guide, vision II is applied on a sub-curricular level (a delimited part of the curriculum) and partly on the activity level. This may seem odd at first glance, but it is logical as (1) vision II should permeate every part of the curriculum, and (2) the practical application by the teacher lies at the sub-curriculum/activity level, which is why the guide lays its focus there.

3.3 The Case for a Scientific Literacy Approach

The two main arguments for applying a scientific literacy approach in Swedish science education exist in the curricular and pedagogic perspectives. The overall curriculum and the science-specific curricula set by Skolverket (Skolverket, 2011) all define both objectives and content in such a way that teachers must teach about the subjects' connections to society to some basic extent, as well as nurture the students' ability to participate in the democratic society. This connecting of the subject to the greater world outside the classroom is inherently a part of the scientific literacy approach.

From a pedagogic viewpoint, the main argumentation lies within cognitivistic (and adjacent) theory, as well as ideas of nurturing the students' interest in science by manifesting the relevancy of the subject to the world they inhabit. In the view of the theory of scaffolding, one can argue that knowledge is something that is *built*. Like parts of a scaffolding, pieces of knowledge are better fastened and structurally sound in the students' minds when well-linked to other pieces of structurally sound knowledge. In this view, there is much to win by connecting subject content to knowledge that the students already possess or at least have a relation to. Several other theories of learning play well into this description. In this context, variation theory is a way of discerning and strengthening links between different pieces of knowledge, whilst associative learning is a physiological explanation of the workings of scaffolding with the extension of the possibility that connections do not necessarily need to be between traditionally related pieces of knowledge. Through the lens of the theory of integrated classroom, it is argued that this socio-scientific connection may be more relevant and motivating for the students, as well as showing the students how the subject knowledge might be used in society, and possible limitations in its application.

Many other theories and learning models may fare well within this framework, however, the listed theories are differentiated as they could be deemed inherent parts of the connection itself, rendering them universal to all applications of the concept.

3.4 The Case for the use of Demonstrations

Going back to the TIMSS study of 2019 and the negative attitudes shown by year 8 students towards science, Lindahl (2003) argues that this may be because of the abstraction and dullness of the science subjects originating from a lack of demonstrations in higher grades, which made the subject more visible, interesting and relevant in lower grades.

The use of laboratory work and/or demonstrations in classroom activities may also be argued for in the view of the same cognitivistic ideas as used in the case of the scientific literacy approach. A visual perspective of the subject in this framework forms a basis for building further understanding or strengthening already existing connections. This is further integrated into this framework through Kolb's theory of experiential learning which describes how students learn through experience, such as real-world demonstration of what the theory describes. Given the four stages of experiential learning, the visualization forms the concrete experience while the teacher leads the reflexive observation, and abstract conceptualization, as well as encouraging active experimentation when practically applicable, either through students participating in laboratory work or by an interactive demonstration by the teacher's hand. There are also, as previously stated in the introduction, suggested advantages of using experiments in instruction to strengthen both motivation and interest in students by showing what they are learning about (Freedman, 1997; Lindahl, 2003), and the same advantages do also exist with science demonstrations (Abrahams & Millar, 2008).

3.5 The Case for the use of Examples

The guide will also give examples in the application of the theory. This is done to give further guidance beyond just the theory, answering questions that may arise about the theory, giving teachers something to compare their ideas against, as well as inspiring teachers in their application. Examples are given in the areas: connections between physics and society, the content and use of demonstration, tasks and exercise, and planning. Most examples are given in short form to not make the guide longer than necessary. It is assumed that the reader is in such a position that they understand the connection. If this is not the case, the guide refers to this thesis for further elaboration.

3.6 Method of Teaching

The main concepts of this thesis could be applied to instruction in the way of the integrated classroom, that being by exploring the subject's connections to the world outside the classroom. This should be done with the concept of building knowledge in mind, linking the subject content to the world so that the students can build and retain a better understanding than they would have if they had only been fed the theory.

The way of connecting can in itself constitute a framework for the instruction. Two examples would be: to teach the subject through the perspective of historical events, a societal issue or popular culture, or to begin with teaching the subject and then explore the subject's impact on society to build relevance and connection to broader non-subject knowledge.

The guide discusses the use of demonstrations and laboratory work in instruction to improve motivation and interest. However, it does not go deep into the methodology of demonstration and laboratory work. This is because the subject is deemed too large to fit in the scope of this thesis and the guide itself. Rather, the use of demonstrations and laboratory work with the aim, or partial aim, to improve the motivation and interest of the students are encouraged.

4
Results

The teacher guide found in Appendix A of this report is the sole result of this thesis. In this chapter, the teacher guide is summarized under the same headings used in the guide itself. It should be noted that the teacher guide is entirely written in Swedish, while the summary here is written in English.

4.1 Background to the Guide and its Aim

This section of the guide introduces the guide itself. It describes why the guide is needed and what it aims to accomplish. The need for the guide is argued in context of the pitfalls of vision I instruction, e.g. lacking relevancy, negative attitudes and low interest among the students, disconnection of the subject and the world it inhabits, and missed opportunities of enhancing understanding and knowledge retention.

The guide's aim is defined and follows the aim of this thesis: to improve student attitudes by supporting science teachers in their application of vision II, by exemplifying the method of connecting subjects to the world outside the classroom within the scope of radiation in the course Physics 1a.

4.2 Description of the Guide

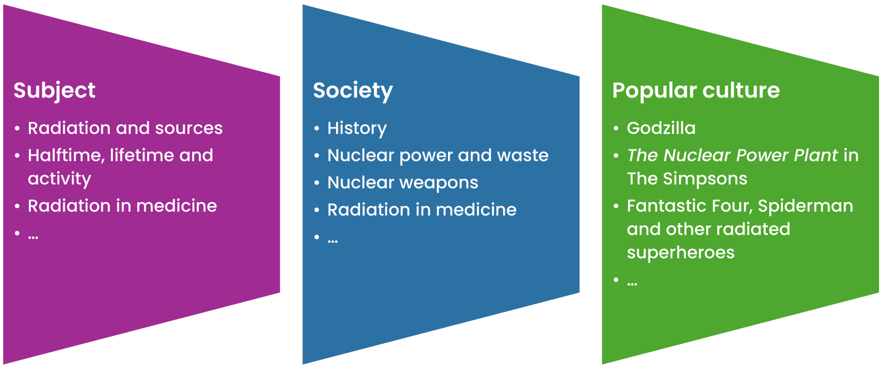
In this section, the material itself is described. It is stated that the main method that the guide advocates is connecting the subject of science to society and the students' everyday lives. The theories and models on which the guide relies are presented. Those are: experiential learning, variation theory, cognitivism/meaningful learning, association, integrated classroom, scientific literacy, bildung and Robert's learning emphases and visions.

The frameworks of the basic questions of didactics and constructive alignment are defined. It is stated that the guide will answer the questions of what and why, while giving guidance to the question of how, which further is broken down to the framework of constructive alignment, where guidance is given for objectives and activity while leaving evaluation to the individual teacher.

Subject, *society* and *popular culture*, shown in Figure 4.1, are introduced as the three main subject areas whose connections should be explored. These are argued to have a causal relationship, where the functions of the subject cause an impact on, and use in, the society which in turn leads to interpretations in popular culture.

Figure 4.1

Subject Areas to Connect



Note. The figure shows the three areas that the guide argues to connect. The graphic is an original work by the author.

A reference is made to the guide's Appendix A, where a rough suggestion of a plan for the subject area is found. It is also stated that, although this guide gives examples within the realm of physics, the method applies to all subjects of science.

4.3 Bildung, Scientific Literacy and Visions

The terms *curriculum emphases*, *visions*, *scientific literacy* and *bildung* are summarized and the differences between the terms are emphasised.

4.4 To Build Understanding

The theoretical concepts used to motivate the advocated method of teaching are described in short, summarized from the theory section of this thesis. The notion that knowledge is something that can be built, as exemplified within the scaffolding model, is emphasised.

4.5 Method of Teaching

In this section of the guide, the method of teaching advocated in this thesis is described. The method is mainly in line with that of the perspective of the integrated classroom. The subject (radiation in the case of the guide) is advocated to be taught/built through connections between the subject, and how it can be seen and used in the world outside the classroom, demonstrating the relevancy of the subject as well as giving the students more opportunities to link the subject knowledge to what they already know. For example, two approaches that the teaching may take are: one may begin teaching the subject alone to later expand the subject to its impact on the world outside, or one may start with one or more societal, political, cultural or other current questions where the subject is prominent and explore the subject within the context of this question.

Cooperation between courses is discussed as a way to connect science to society. It is expressed that there is a practical need for the teacher to have the ability to connect the subject to society by themselves, as time for cooperation could be limited. This is needed for the teacher to be able to meet the objectives of the curriculum, and to successfully adhere to the methods advocated for within the guide during all lessons. Lastly, the use of demonstrations and laboratory work to improve students' motivation and interest, and to have this as an aim, is discussed and encouraged.

4.6 Examples of Connections and Content

In this section, connections are explored between the subject of radiation, society, and popular culture. The section contains five tables, all of which are translated and inserted here as Tables 4.1, 4.2, 4.3, 4.4 and 4.5. The first three tables define the subject content, societal topics, and popular culture. The last two tables show connections that could be made between the three subject areas by starting either from a subject perspective or a societal perspective. It is emphasised that the connections made in no way constitute a complete list of possible connections, and what connections are possible is probably limited mainly by the creativity of the individual teacher. The content of Table 4.1 is largely decided within the curriculum set by Skolverket. However, the depth of each topic is determined at large by the individual teacher. Each category is previously summarized in Chapter 2.

Table 4.1

Proposed Subject Content Applicable Within the Course Physics 1a

Subject	
Category	**Content**
Radiation	Alpha, beta and gamma radiation.
Sources	Uranium and other unstable nuclides.
Light and its properties	Wave and particle properties, energy and frequency relationships.
Half-life, lifetime and activity	Half-life, lifetime, activity, units, differences in the lifetimes of different radiation sources.
Dose, effective dose and units	Dose, effective dose, units, energy deposition and ionization.
Radiation penetration capacity	Penetration of alpha, beta and gamma radiation.
Background radiation	Cosmic radiation, Uranium in the bedrock, Radon in buildings.
Radiation in medicine	X-ray and other imaging techniques, cancer treatment.
Radiation safety	Precautions to protect against radiation.

The content of Table 4.2 are societal concepts with connections to radiation, which are described in Chapter 2.

Table 4.3 contains a list of references to radiation made in popular culture, and descriptions of what could be discussed. Further reference is made to the compilation of pop-culture references to radiation, created by The University of Alabama at Birmingham (n.d.).

Table 4.4 presents possible connections to societal and popular culture topics presented in Tables 4.2 and 4.3, based on the different sub-subjects within the subject of radiation.

Table 4.5 presents possible connections to subject and popular culture presented in Tables 4.1 and 4.3, based on the societal topics presented in Table 4.2.

Table 4.2

Proposed Societal Concepts With Connection to the Subject

Society	
Category	**Content**
History	• Henri Becquerel. • Curie Wall. • Development of knowledge on the subject. • Use in technology.

Nuclear weapons	• Hiroshima and Nagasaki
	  ○ History (with effect on the population).
	  ○ Concern of the creation of hell on earth.
	  ○ Illness and recovery.
	• Nuclear weapons test and background radiation.
	• Radioactive fallout.

Nuclear power and nuclear waste	• The function of nuclear power. • Nuclear waste and storage.
Nuclear accidents	• Tjernobyl. • Fukushima. • Three Mile Island.
Age determination	• Carbon-14 and other similar methods.
Radiation in medicine	• X-rays and other imaging techniques. • Cancer treatment.
Radiation and disease	• Radiation sickness. • Cancer due to rdiation. • Risk and amount of radiation.
Fear and stigmatization of people and areas	• Accident in Brazil where people came into close contact with medical nuclear waste. • Fukushima and Chernobyl today. • Deaths during evacuation of Fukushima. • Unreasonably high costs per life-year saved for nuclear security measures.
Background radiation and radon in the homes	• Cosmic radiation. • Uranium in the bedrock. • Radon in buildings. • Nuclear testing.

Table 4.3

Short List of References to the Subject Made in Popular Culture

Popular Culture	
Category	**Content**
The Nuclear Power Plant in the TV-series *The Simpsons*	Inaccuracies in the popular TV series that likes to poke fun at people's notions.
Godzilla	Japan's trauma from the atomic bombs and how it is reflected in Godzilla.
Fantastic Four, Spiderman and other irradiated superheroes	How the effects of radiation on the body are represented in the media.
Mutated animals and mutants	E.g. three-eyed fish in *The Simpsons.*
The TV series *Chernobyl*	A metaphor is used where they describe radiation "like small bullets", is that a good description? What distinguishes radiation from rifle bullets in how they cause damage?
Computer Game Series *Fallout*	Fear of nuclear weapons and concern about hellish landscapes as a result of nuclear weapons.

Table 4.4

Proposed Connections to Society and Popular Culture Based on the Subject

Connections from Subject to Society and Popular Culture		
Subject	**Society**	**Popular culture**
Radiation	• Sickness and medical care. • Background radiation. • Radiation safety. • Nuclear power. • Nuclear weapons.	• The metaphor in the TV-series *Chernobyl*. • *The Nuclear Power Plant* in the TV series *The Simpsons*. • *Godzilla.*
Sources	• Waste management. • Safe storage. • Uses of different radiation sources. • Nuclear power. • Nuclear weapons.	• The metaphor in the TV-series *Chernobyl*. • *The Nuclear Power Plant* in the TV series *The Simpsons*. • *Godzilla.*
Light and its properties	• X-rays and gamma rays. • UV radiation from the sun.	E.g. trends in tanning yourself.
Half-life, lifetime and activity	• Age determination. • Radioactive discharges (e.g. Chernobyl).	• The *Fallout* video game series . • Fictional depictions of the aftermath of nuclear war and the like.
Background radiation	• Radon in homes. • Cosmic radiation. • Nuclear weapons.	• The *Fallout* video game series . • Fictional depictions of the aftermath of nuclear war and the like.
Dose, effective dose and units	• Sickness and medical care. • Sources and Doses/Activity.	• *Godzilla.* • *Fantastic Four, Spiderman* and other irradiated superheroes.
Radiation penetration capacity	• Sickness and medical care. • Radiation safety.	E.g. private and public bunkers.
Radiation in medicine	• Illness. • X-rays and other imaging techniques. • Cancer treatment. • Stigmatization.	• *Godzilla.* • *Fantastic Four, Spiderman* and other irradiated superheroes. • Japan's trauma from the atomic bombs and how it is reflected in Godzilla.

Table 4.5

Proposed Connections to Subject and Popular Culture Based on Societal Concepts

Connections from Society to Subject and Popular Culture		
Society	**Subject**	**Popular culture**
History	Probably the whole area based on a well-chosen historical description.	Most things related to radioactivity and radiation.
Nuclear weapons	• Radiation, Radiation sources and light. • Half-life, lifetime and activity. • Dose, effective dose, and units. • Radiation safety.	• Godzilla. • The *Fallout* video game series. • The Movie *Oppenheimer.*
Nuclear power and nuclear waste	• Radiation, Radiation sources and light. • Half-life, lifetime and activity. • Radiation safety.	• The metaphor in the TV series *Chernobyl*. • *The Nuclear Power Plant* in the TV series *The Simpsons.*
Nuclear accidents	• Radiation, Radiation sources and light. • Half-life, lifetime and activity. • Radiation safety.	• The metaphor in the TV series *Chernobyl*. • *The Nuclear Power Plant* in the TV series *The Simpsons.*
Age determination	• Radiation, Radiation sources and light. • Half-life, lifetime and activity. • Background radiation.	-
Radiation in medicine	• Radiation, Radiation sources and light. • Dose, effective dose, and units. • The penetration capacity of radiation. • X-rays and other imaging techniques. • Cancer treatment. • Radiation safety.	• *Fantastic Four, Spiderman* and other irradiated superheroes. • Mutated animals and mutants.
Radiation and disease	• Radiation, Radiation sources and light. • Dose, effective dose, and units. • Radiation safety.	• *Fantastic Four, Spiderman* and other irradiated superheroes. • Mutated animals and mutants.
Fear and stigmatization of people and areas	• Radiation, Radiation sources and light. • Radiation safety. • Dose, effective dose, and units. • Background radiation.	• Godzilla. • The *Fallout* video game series.
Background radiation and radon in the home	• Radiation, Radiation sources and light. • Radiation safety. • Dose, effective dose, and units. • Background radiation.	The *Fallout* video game series.

4.7 Parts and Structures

In this section of the guide, three ways of structuring the radiation subject are presented. These are: (1) dividing the area into several sub-areas that deal with related concepts that can be reconnected to each other and where the same social and cultural connections can be used to expand several concepts, (2) putting the subject in the context of a historical description, alternatively a social or popular culture description and develop the area within the context of the description, (3) beginning each new area with a lab/demonstration that relates, anchors and builds a foundation for the upcoming area. All three are exemplified in the example plan given in the guide's appendix.

4.8 Closing Thoughts

This section restates the aim of the guide: to advocate for, and guide in, the use of vision II and demonstrations in science education, from the perspective of what is demanded by the curriculum, as well as the didactic possibilities.

An argument points out that this integrated perspective might be assumed to be more difficult in application for some subjects than others, exemplified by the theory-heavy subjects of quantum mechanics and general relativity, which are found within the curriculum. It is argued that this thesis has shown that even the seemingly theory-heavy subject of radiation has plenty of relevant connections to the world outside the classroom, and quantum computing, radioactive decay, timekeeping in satellites, and relative time in space voyages near the speed of light are listed as examples of how even such intangible subjects as quantum mechanics and general relativity are well-connected to the world outside the classroom.

4.9 Appendices

The teacher guide contains two appendices. The first appendix, Appendix A, contains an example plan for the subject area of radiation, a description of the demonstrations/laboratory work exemplified in the guide, and three examples of tasks that comply with the integrated perspective. The second appendix, Appendix B, contains the relevant aims and the central content of the course Physics 1a.

5

Conclusion

5.1 Discussion and Future Research

In the light of the TIMSS survey of 2019 (Skolverket, 2020), which showed that a large share of Swedish year 8 students expresses negative attitudes towards science, it is clear that contemporary science instruction is inadequate. Although TIMSS only surveys year 4 and 8 students, the large share of year 8 students with negative attitudes can probably be interpolated to adjacent grades. As a whole, this includes hundreds of thousands of students in just the Swedish school system. There is a need for change. The teacher guide developed within this thesis aims to improve student attitudes by encouraging the use of vision II instruction, and demonstration. The case for vision II seems strong, whether arguing from the perspectives of the current curriculum Gy11, democratic values, cognitive theories of learning and instruction, or the interest and motivation of the students. The guide developed within this thesis has the potential to give a decent basis for physics teachers in connecting radiation to the world of the students, and hopefully, it provides enough guidance for other teachers to transfer the spirit of the connections into other science courses, to improve the attitudes of the students towards science and the world it describes.

The efficacy of the teacher guide is left unevaluated, which means that we do not know if the guide constitutes good support for the teachers in practice. However, previous research points to the feasibility of using demonstrations and a scientific literacy perspective to improve the motivation and interest of students. What is left to answer is whether the guide argues for these benefits well enough, and if the concepts within the guide are explained well enough.

As I see it, several important questions are left unanswered in previous research related to vision II instruction. Does the low application rate of vision II (Engström & Carlhed, 2014) originate from a lack of knowledge, which is assumed in the aim of the teacher guide, or does it originate from something else? Although the lack of adequate knowledge is supported within the literature (Bransford et al., 1999; Nilsson, 2012; Roberts, 2007), such things as lacking time resources and/or a culture aligned with a vision I perspective could also be culprits in the lack of vision II perspective. Additionally, there seems to exist a gap in the research on the attitudes towards science of students at the upper secondary level. Skolverket does not measure this, and its statistical department has no knowledge of other studies that do (personal communication, 11 April 2024). This calls for a study to learn to what degree the results of the 2019 TIMSS survey apply to these students, and by extension if the motivational argument for the content of the teacher guide holds for the course Physics 1a, to which it is applied.

The work within this thesis reinforces the reasoning by Bransford et al. (1999), which is that teachers have very limited time to broaden their knowledge within teaching. The work that has been conducted within this thesis could be thought of as a benchmark for the work a teacher would have to do to enlighten themselves in the matter of scientific literacy, excluding the process that led them to scientific literacy to begin with, and the whole journey from seeing a problem in their instruction, to diving into the jungle that is educational research. The extensive theory section, and the more than fifty different sources used in this work, many of which are found behind rather tall paywalls, witness of the odds stacked against them. It should not be hard to understand that many teachers have difficulty, and do not have enough time, to navigate the research on their own. This may lead to a systematic obsolescence of the teaching styles of ageing teachers if they do not receive further education after their initial education to become teachers. It seems paramount that Skolverket, and perhaps the schools themselves, take action in the ongoing education of Swedish teachers. Documents and online research compilations like Nilsson (2012) and Skolverket (2023) show that Skolverket does take action to help teachers in their research. However, if their actions are enough is left as an open question.

5.2 Societal, Ethical and Ecological Aspects

This work has a clear societal connection, as the main idea discussed and promoted within it is the literal connection between science and society, through the perspective of scientific literacy. Instruction following vision II has the inherent aim (or emphasis) to bring scientific thought and competence with the students into society. This scientific literacy should assist the individual in their everyday lives, and bring more scientific reasoning into the democratic process, paving the way for societal change built on scientific principles. This has a clear connection to ecological aspects, as sustainable development, and human interaction with ecological concepts in general, are scientific concepts and problems well within the realm of vision II instruction, but not within vision I. From an ethical perspective, this work has no obvious downside regarding human lives, while the benefit should be clear.

Bibliography

Abrahams, I., & Millar, R. (2008). Does practical work really work? a study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education*, *30*(14), 1945–1969. https://doi.org/10.1080/09500690701749305

Aikenhead, G. S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education*, *27*(1), 1–52. https://doi.org/10.1080/03057269608560077

Aikenhead, G. S. (2007). Expanding the research agenda for scientific literacy. *Promoting scientific literacy: Science education research in transaction*, *64*.

Andersson, P., Carlsson, M., Falk, R., Hubbard, L., Leitz, W., Mjönes, L., Möre, H., Nyblom, L., Söderman, A.-L., Lasson, K. Y., Åkerblom, G., & Öhlén, E. (2007). *Strålmiljön i sverige*. Strålsäkerhetsmyndigheten.

Anisfield, N. (1995). Godzilla/gojiro: Evolution of the nuclear metaphor. *The Journal of Popular Culture*, *29*(3), 53–62. https://doi.org/10.1111/j.0022-3840.1995.00053.x

Bates, B. (2023). *Learning theories simplified*. Sage Publications.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (1999). *How people learn : Brain, mind, experience, and school*. National Academies Press.

Bruner, J. S. (1960). *The process of education*. Harvard Univer. Press.

Bryce, T. G. K., & Blown, E. J. (2023). Ausubel's meaningful learning re-visited. *Current Psychology*. https://doi.org/10.1007/s12144-023-04440-4

Centers for Disease Control and Prevention. (2014). https://www.cdc.gov/nceh/radiation/fallout/rf-gwt_home.htm

Chaloner, C. (1997). The most wonderful experiment in the world: A history of the cloud chamber. *The British Journal for the History of Science*, *30*(3), 357–374. http://www.jstor.org/stable/4027867

Colombia Center for Nuclear Studies. (2012). https://k1project.columbia.edu/news/hiroshima-and-nagasaki

DeBoer, G. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *J Res Sci Teach*, *37*, 582–601. https://doi.org/10.1002/1098-2736(200008)37:63.0.CO;2-L

Domenech, H. (2017). *Radiation safety: Management and programs*. Springer International Publishing.

Engström, S., & Carlhed, C. (2014). Different habitus: Different strategies in teaching physics? relationships between teachers' social, economic and cultural capital and strategies in teaching physics in upper secondary school. *Cultural Studies of Science Education*, *9*(3), 699–728. https://doi.org/10.1007/s11422-013-9538-z

Freedman, M. P. (1997). Relationship among laboratory instruction, attitude toward science, and achievement in science knowledge. *Journal of Research in Science Teaching*, *34*(4), 343–357. https://doi.org/10.1002/(SICI)1098-2736(199704)34:4<343::AID-TEA5>3.0.CO;2-R

Giesecke, J. A., Burns, W. J., Barrett, A., Bayrak, E., Rose, A., Slovic, P., & Suher, M. (2012). Assessment of the regional economic impacts of catastrophic events: Cge analysis of resource loss and behavioral effects of an rdd attack scenario. *Risk Analysis*, *32*(4), 583–600. https://doi.org/https://doi.org/10.1111/j.1539-6924.2010.01567.x

Gordon, A., Quadflieg, S., Brooks, J. C., Ecker, U. K., & Lewandowsky, S. (2019). Keeping track of 'alternative facts': The neural correlates of processing misinformation corrections. *NeuroImage*, *193*, 46–56. https://doi.org/https://doi.org/10.1016/j.neuroimage.2019.03.014

Grzywa-Celińska, A., Krusiński, A., Mazur, J., Szewczyk, K., & Kozak, K. (2020). Radon-the element of risk. the impact of radon exposure on human health. *Toxics*. https://doi.org/10.3390/toxics8040120

Haglund, J., & Hultén, M. (2017). Tension between visions of science education. *Science & Education*, *26*, 323–344. https://doi.org/10.1007/s11191-017-9895-1

Hebb, D. (2002). *The organization of behavior : A neuropsychological theory*. Psychology Press.

Jelinek, C., & Eliasson, T. (2015). *Strålning från bergmaterial*. Swedish Geological Survey.

Kolb, D. (1984, January). *Experiential learning: Experience as the source of learning and development* (Vol. 1).

Leiserowitz, A., Maibach, E., Roser-Renouf, C., & Smith, N. (2011, April). *Climate change in the american mind: Americans' global warming beliefs and attitudes in may 2011*. Yale University and George Mason University. http://environment.yale.edu/climate/files/ClimateBeliefsMay2011.pdf

Lindahl, B. (2003). *Lust att lära naturvetenskap och teknik? : En longitudinell studie om vägen till gymnasiet* [Doctoral dissertation, University of Gothenburg. Faculty of Education]. Acta Universitatis Gothoburgensis.

Lo, M. (2012). *Variation theory and the improvement of teaching and learning*. Acta universitatis Gothoburgensis.

Martin, B. R., & Shaw, G. (2019). *Nuclear and particle physics - an introduction* (third edition). Wiley.

Mazin, C., & Renck, J. (2019). Chernobyl.

McCrory, P. (2021). *In defence of the classroom science demonstration*. https://hooktraining.com/defence-of-science-demonstrations/

Munroe, R. (n.d.). https://xkcd.com/radiation/

Nilsson, P. (2012, January). *Att se helheter i undervisningen – naturvetenskapligt perspektiv*. Skolverket.

Nordling, C., & Österman, J. (2020). *Physics handbook for science and engineering*. Studentlitteratur AB.

Office of Nuclear Energy. (2018). *7 things the simpsons got wrong about nuclear*. https://www.energy.gov/ne/articles/7-things-simpsons-got-wrong-about-nuclear

Ohba, T., Tanigawa, K., & Liutsko, L. (2021). Evacuation after a nuclear accident: Critical reviews of past nuclear accidents and proposal for future planning. *Environment International*, *148*, 106379. https://doi.org/10.1016/j.envint.2021.106379

Perko, T. (2014). Radiation risk perception: A discrepancy between the experts and the general population [Environmental Radioactivity: Implications for Human and Environmental Health - International Symposium at Plymouth University, UK]. *Journal of Environmental Radioactivity*, *133*, 86–91. https://doi.org/10.1016/j.jenvrad.2013.04.005

Petterson, J. S. (1988). Perception vs. reality of radiological impact: The goiania model. *Nuclear News*, *31*(14), 84–90.

Rennie, L. J., Venville, G., & Wallace, J. (2011). Learning science in an integrated classroom: Finding balance through theoretical triangulation. *Journal of Curriculum Studies*, *43*(2), 139–162. https://doi.org/10.1080/00220272.2010.509516

Ritchie, H. (2017). What was the death toll from chernobyl and fukushima? [https://ourworldindata.org/what-was-the-death-toll-from-chernobyl-and-fukushima]. *Our World in Data*.

Roberts, D. A. (1982). Developing the concept of "curriculum emphases" in science education. *Science Education*, *66*(2), 243–260. https://doi.org/10.1002/sce.3730660209

Roberts, D. A. (2007). Scientific literacy/science literacy. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 729–780). Routledge.

Roberts, D. A. (2011). Competing visions of scientific literacy: The influence of a science curriculum policy image. *Exploring the Landscape of Scientific Literacy*, 11–27.

Sandman, P. M., Weinstein, N. D., & Klotz, M. L. (1987). Public response to the risk from geological radon. *Journal of Communication*, *37*(3), 93–108. https://doi.org/10.1111/j.1460-2466.1987.tb00997.x

Sjöström, J., & Eilks, I. (2018). Reconsidering different visions of scientific literacy and science education based on the concept of bildung. In Y. J. Dori, Z. R. Mevarech, & D. R. Baker (Eds.), *Cognition, metacognition, and culture in stem education: Learning, teaching and assessment* (pp. 65–88). Springer International Publishing. https://doi.org/10.1007/978-3-319-66659-4_4

Skolinspektionen. (2018). *Fysik utan dragningskraft*. Skolinspektionen.

Skolverket. (n.d.). *Styrdokumenten sätter ramarna för ditt arbete*. https://www.skolverket.se/undervisning/gymnasieskolan/laroplan-program-och-amnen-i-gymnasieskolan/styrdokumenten-satter-ramarna-for-ditt-arbete-i-gymnasieskolan

Skolverket. (2011). Läroplan för gymnasieskolan: Gy11. https://www.skolverket.se/undervisning/gymnasieskolan/laroplan-program-och-amnen-i-gymnasieskolan/laroplan-gy11-for-gymnasieskolan

Skolverket. (2020). *TIMSS 2019. svenska grundskoleelevers kunskaper i matematik och naturvetenskap i ett internationellt perspektiv*. Skolverket. https://www.skolverket.se/publikationer?id=7592

Skolverket. (2023). Sammanställning och spridning av forskningsresultat. Retrieved March 14, 2024, from https://www.skolverket.se/skolutveckling/forskning-och-utvarderingar/sammanstallning-och-spridning-av-forskningsresultat

Slovic, P. (2012). The perception gap: Radiation and risk. *Bulletin of the Atomic Scientists*, *68*(3), 67–75. https://doi.org/10.1177/0096340212444870

Snowden, M. (2013). 1 - the diffusion cloud chamber. In O. FRISCH (Ed.), *Progress in nuclear physics (second edition)* (Second Edition, pp. 1–17). Pergamon. https://doi.org/10.1016/B978-1-4831-9989-4.50004-5

Strålsäkerhetscentralen. (2016). *Användning av strålkällor i skolor och vid läroanstalter*. Strålsäkerhetscentralen.

Strålsäkerhetsmyndigheten. (2018). *Laboratoriearbete med öppna strålkällor*. https://www.stralsakerhetsmyndigheten.se/omraden/forskning/starta-forskningsverksamhet-med-joniserande-stralning/laboratoriearbete/

Strålsäkerhetsmyndigheten. (2022). *Att mäta radon*. https://www.stralsakerhetsmyndigheten.se/omraden/radon/att-mata-radon/

Strålsäkerhetsmyndigheten. (2024). https://www.stralsakerhetsmyndigheten.se/omraden/radioaktivt-avfall/slutforvar/hantering-av-radioaktivt-avfall-fran-karntekniska-anlaggningar/

Tengs, T. O., Adams, M. E., Pliskin, J. S., Safran, D. G., Siegel, J. E., Weinstein, M. C., & Graham, J. D. (1995). Five-hundred life-saving interventions and their cost-effectiveness. *Risk analysis*, *15*(3), 369–390.

The University of Alabama at Birmingham. (n.d.). *Uab radiation pop culture project*. https://www.uab.edu/shp/cds/health-physics/radiation-pop-culture-project

Uretsky, J. L. (1997). Penetration of cosmic ray muons into the earth. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, *399*(2), 285–300. https://doi.org/10.1016/S0168-9002(97)00996-0

Yngvesson, U. (2018). *Strålsäkerhetsmyndighetens föreskrifter om röntgenutrustningar och slutna strålkällor som används vid skolor*. Strålsäkerhetsmyndigheten.

Yoshinaga, K., Kubota, M., & Kamata, M. (2014). Simple cloud chambers using a freezing mixture of ice and cooking salt. *Physics Education*, *50*(1), 23. https://doi.org/10.1088/0031-9120/50/1/23

A

The teacher guide

In this appendix, the teacher guide that is the result of this thesis is presented in its entirety. It is aimed towards Swedish science teachers, and is therefore written in Swedish. However, the guide is in many ways a summary of this thesis. Those who have read this thesis will find little new in the teacher guide.

ATT FÖRA ÄMNET NÄRMARE ELEVEN

En guide till Vision II-undervisning och förbättrandet av attityder till naturvetenskapen

Kalle Svensson

CHALMERS TEKNISKA HÖGSKOLA

Innehållsförteckning

Att föra ämnet närmare eleven

Bakgrund till guiden samt dess syfte

Traditionellt sett så har undervisning i de naturvetenskapliga ämnena ofta förbisett ämnenas plats i elevernas vardag och i världen runt omkring dem, vilket har orsakat en frånkoppling mellan ämne och tillämpning [1], ett minskat intresse för ämnet hos elever [2], samt missade möjligheter att förstärka elevernas kunskaper [3].

Denna guide riktar sig till lärare inom naturvetenskapliga kurser och är ämnat att stödja lärare i undervisningen genom att vägleda i *scientific literacy* och angränsande teori. Guiden ger exempel inom ramen för gymnasiekursen *Fysik 1a,* med målet att göra det centrala innehållet inom radioaktivitet och strålning mer intressant, holistiskt och greppbart för eleverna, och samtidigt främja de mål om demokrati och samhällskoppling som finns i läro- respektive kursplanen. Det naturvetenskapliga ämnet aktualiseras i guiden genom ämnets koppling till samhället, ämnets historia och ämnets påverkan på elevernas vardag. Dessutom förs ämnet närmare eleverna genom visualisering av den annars osynliga strålningens rörelse i rummet genom användandet av dimkammare.

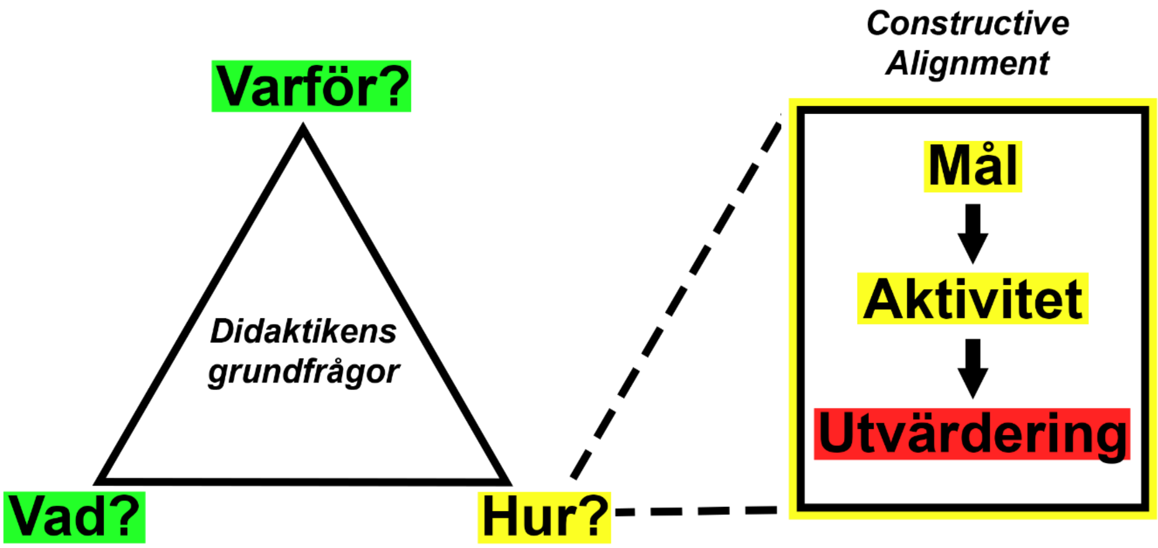
Att guiden berör just radioaktivitet och strålning beror på att det är ett bra exempel på område inom fysikämnet som har många kopplingar till sammanhang i världen utanför klassrummet, samtidigt som ämnet och dess funktion är bra exempel på sådant som i allmänhet är teoretiskt bundet och osynligt för eleven.

Guiden har tagits fram som del av ett mastersarbete på Chalmers Tekniska Högskola våren 2024. Tesen för arbetet återfinns via Chalmers Open Digital Repository under titeln *How to bring the subject closer to the student - Developing a teacher guide to Vision II instruction.*

Beskrivning av guiden

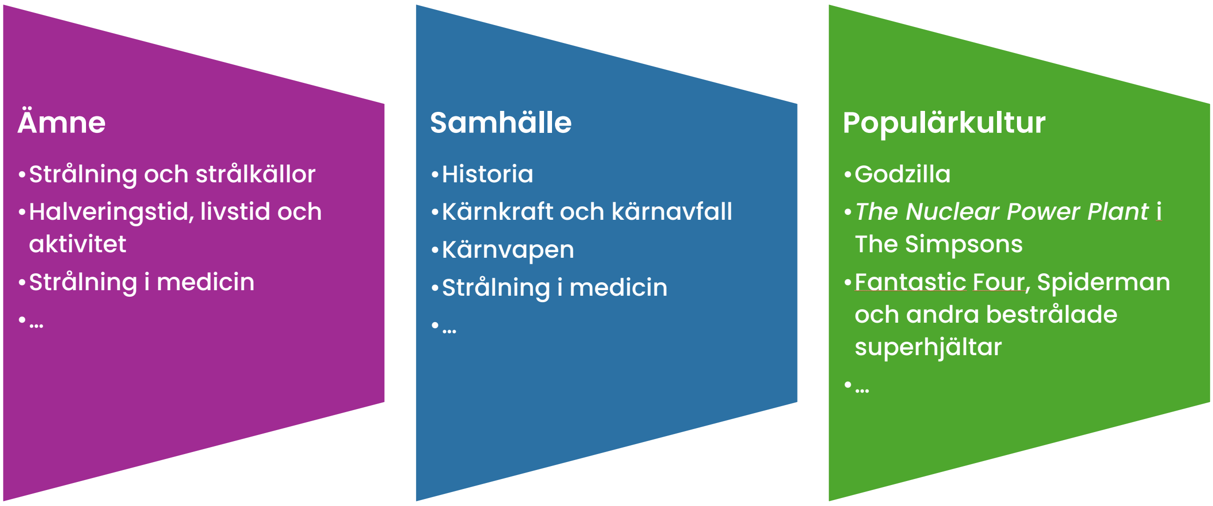
Inom denna guide används kopplingen mellan fysik, samhället och elevernas egna liv och vardag för att aktualisera ämnet radioaktivitet och strålning för eleverna. Guiden bygger på flera utbildningsvetenskapliga modeller, teorier och ramverk, där de mest centrala är *scientific literacy, Roberts lärandeemfaser* och *visioner* [4] [5]*, integrated classroom* [6]*, samt scaffolding* [7]. Guiden utgår även ifrån lärandeteorierna/modellerna *upplevelsebaserat lärande* [8]*, variationsteori* [9]*, associativt lärande* [10]*, och bildning* [4].

Ur ett bredare didaktiskt perspektiv så svarar guiden på de didaktiska grundfrågorna *vad?* och *varför?* [11] och ger vägledning till hur man kan besvara den tredje didaktiska grundfrågan *hur?* I det ramverk som på engelska kallas för *constructive alignment* [12] så formulerar läraren mål för undervisningen, som denna sedan designar aktiviteten för att uppfylla, för att sedan utvärdera om målen blivit uppfyllda. Constructive alignment kan argumenteras för att utgöra en fördjupning av *hur*-frågan. Ur det perspektivet så lämnas i denna guide formuleringen av specifika mål samt genomförandet av utvärdering till den enskilda läraren. Guiden utgör dock inspiration för aktiviteten utifrån de bredare mål som definierats av Skolverket, samt de som definieras inom vision II i form av Roberts emfaser. I Figur 1 visas detta upplägg, där grönt är sådant som besvaras i guiden, gult är sådant som guiden ger ledning till, och rött är sådant som inte berörs.



***Figur 1**: Vad guiden besvarar (grönt), ger ledning till (gult) och inte ger ledning till (rött).*

Det föreslagna innehållet i guiden kan delas upp i de tre huvudområdena *ämne, samhälle* och *populärkultur*, vilket visas i Figur 2. Mellan huvudområdena finns det ett orsakssamband: funktionerna i ämnet orsakar påverkan och användning i samhället som i sin tur leder till tolkningar i populärkulturen. Guiden bygger på upprepad koppling mellan dessa huvudområden för att bygga förståelse, association och intresse hos eleverna.



***Figur 2**: Områden att koppla samman och exempel på innehåll.*

I Appendix A så presenteras ett översiktligt förslag på planering för det aktuella området tillsammans med kort beskrivning av föreslagna laborationer och en samling aktivitetsexempel.

Denna guide och det arbetssätt den främjar är inte avgränsat till kontexten som gäller i denna guide, utan det kan även appliceras på andra delar av fysiken och de naturvetenskapliga ämnena i övrigt.

Bildning, scientific literacy och visioner

Varför ska elever lära sig naturvetenskap? Som svar på den frågan definierar Douglas Roberts sju emfaser i läroplaner [5]:

1. **The "Everyday Coping" emphasis:** Som namnet antyder säger denna emfas att vetenskap är ett viktigt medel för att förstå och kontrollera sin närmiljö, antingen naturligt eller tekniskt. Utbildningen ska ta upp vetenskapligt innehåll som eleven kommer att möta i sin vardag.

2. **The "Structure of Science" emphasis:** Denna emfas behandlar hur vetenskap som ämne växer och utvecklas. Genom upprepade diskussioner om till exempel samspelet mellan bevis och teori, eller modeller och deras lämplighet för att förklara vissa fenomen, så utökas vetenskapsämnet för eleven.

3. **The "Science, Technology and Decisions" emphasis:** Denna emfas fokuserar på naturvetenskapens och teknikens begränsningar i att hantera praktiska angelägenheter, antingen privata eller offentliga. Vetenskap skiljer sig från teknik, och praktiska problem skiljer sig tydligt från vetenskapliga problem,

där praktiska problem kräver ett försvarbart beslut och vetenskapliga problem kräver ny vetenskaplig kunskap.

4. **The “Scientific Skill Development” emphasis:** I denna emfas är målet inte att förvärva kunskap, utan att få kompetens i den vetenskapliga processen och vad den innebär.

5. **The “Correct Explanation” emphasis:** Vetenskapens produkter är otvivelaktigt korrekta och vetenskaplig kunskap utgör en samling fakta som eleven bör lära sig utan tvekan om huruvida den är korrekt eller inte. Den vanliga föreställningen om "bemästra nu, fråga senare" är en del av denna emfas.

6. **The “Self as Explainer” emphasis:** Denna emfas kommunicerar vetenskapen som en kulturell institution, och dess plats i historien, som drivs av och driver mänsklig utveckling vid sidan av andra förklaringssystem som religion och magi.

7. **The “Solid Foundation” emphasis:** Den naturvetenskap som nu lärs ut är en förberedelse för senare studier som ska påbörjas på nästa nivå i skol-systemet, och detta ska kommuniceras till eleverna. Det som lärs ut i grundskolan ska förbereda för gymnasieskolan, som i sin tur ska förbereda för ett framtida, mindre definierat syfte, till exempel studier vid ett universitet. Det är sällan känt vilken slutlig uppsättning mål som den tidigare instruktionen ska riktas mot.

De två emfaserna “Solid Foundation" och "Correct Explanation" är i stort sett historiska reliker som inte används längre i diskussionen kring läroplaner [4]. Resterande emfaser grupperas av Roberts inom två *visioner, Vision I* och *Vision II.* Vision I är ett traditionellt perspektiv på undervisningen i naturvetenskap och innefattar emfaserna "Scientific Skill Development” och "Structure of Science". Vision II är en utökning av Vision I som också innehåller emfaserna “Everyday Coping,” “Science, Technology and Decisions,” och “Self as Explainer”. Denna Vision II är en del av en bredare diskussion kring termen *scientific literacy*, som i korthet handlar om att lära sig naturvetenskap och teknik för livet och inte för specifika naturvetenskapliga eller tekniska karriärer. Scientific literacy står mycket nära de svenska begreppen *bildning*, *folkbildning* och *allmänbildning*, och har i allmänhet en mycket nära koppling till demokratiska värden [13]. Begreppen skiljer sig i att scientific literacy mest handlar om att kunna använda naturvetenskap i livet medan bildningsbegreppet är bredare och trycker på att man ska kunna använda allehanda kunskap, inte enbart naturvetenskap, i sitt liv som demokratisk medborgare.

Att bygga förståelse

Inom pedagogiska modeller och teorier inom områdena kognitivism och neuro-didaktik talar man ofta om hur man *bygger* kunskap och förståelse hos elever genom att koppla ihop ny kunskap med redan befintlig kunskap och förståelse hos eleverna [14]. Tre framträdande teorier är: Ausubels *meningsfullt lärande* [7], som säger att effektivt lärande uppstår när eleverna kan koppla ny information med tidigare erfarenheter för att skapa ny förståelse; Bruners teori om *scaffolding* (där *byggställning* fungerar som en relativt bra översättning och metafor), som beskriver lärande som byggandet av fysiska ställningar, alltså att bygga ny förståelse och kunskap på den redan befintliga ställningen nedan för att bilda en ny större bild av förståelse och kunskap [7]; och Hebbs teori om *associativt lärande* som säger att områden i hjärnan som aktiveras samtidigt upprepade gånger kommer kopplas samman och fortsätta aktiveras tillsammans [10]. Även *variationsteori,* där förståelse för ett lärandeobjekt antas komma från vad som skiljer lärandeobjektet från andra objekt, kan tänkas aktuellt i byggandet av förståelse och kunskap för att stärka definitioner, differentiera närliggande kunskaper och påvisa relationer mellan kunskaper [9].

Med dessa modeller och teorier som grund så kan man genom ständig koppling och jämförelse mellan ämne, samhälle och kultur i den naturvetenskapliga utbildningen bygga ett omfattande nätverk av kunskaper som kopplar till, bygger på, och förstärker varandra. Samtidigt öppnar man upp för möjligheten att förankra nya kunskaper i redan existerande uppfattningar om begrepp i elevens vardag, och ger eleven förståelse och verktyg att använda i sitt liv som demokratisk medborgare. Detta arbetssätt kan argumenteras för att omfattas inom teorin *integrated classroom,* som argumenterar för att sätta det natur-vetenskapliga ämnet i ett interdisciplinärt sammanhang för att ge ett integrerat/holistiskt perspektiv på ämnet och dess plats och funktion utanför klassrummet, samtidigt som ämnet kan göras mer relevant och intressant för eleven genom koppling till världen denne lever i [6].

I vissa sammanhang kan det tänkas fördelaktigt att synliggöra annars osynliga och svårgripbara processer och begrepp för eleven. Detta exemplifieras i denna guide genom radioaktivitet och strålning som ämne, där den osynliga strålningen omkring oss synliggörs genom laboration med dimkammare, som synliggör strålbanorna för joniserande strålning. Förutom att på så sätt skapa fler kunskaps- och förståelsestrukturer att bygga vidare på, så anknyter det även till Kolbs lärandemodell *experiential learning* som förespråkar lärandesituationer där eleverna kan få egna erfarenheter av det aktuella ämnet i världen omkring dem [8]. Dessutom är argumentationen för att demonstrationer och laborationer bygger intresse och motivation hos eleverna relativt stark, och elever vittnar om att en stor del av vad som gör ämnet intressant och roligt är just demonstrationer och laborationer där de får lära känna ämnet [15] [16].

Arbetssätt som lärare

Utifrån föregående avsnitt kan man dra slutsatserna att den undervisning som enbart rör sig inom ramen för Vision I ger en snäv bild av naturvetenskapen, minskar elevernas möjligheter att förstärka sina kunskaper, missar möjligheter att väcka elevers intresse, och inte når upp till Skolverkets mål om demokrati och samhällskoppling. Som lärare bör man därför alltid utgå från alla fem emfaser som tillhör Vision II när man utformar sin undervisning.

Inom denna guide förespråkas undervisning som utforskar ämnet genom de tre tidigare nämnda huvudområdena/perspektiven *ämne, samhälle* och *populär-kultur.* På så sätt så kan man både ge eleverna förståelse för sin omvärld och ämnet, samtidigt som deras kunskaper inom ämnet blir starkare förankrade än om de hade studerat ämnet isolerat från omvärlden. Dessa tre perspektiv kan användas på flera sätt. Här följer två exempel på hur man kan angripa ett ämne.

1. Man kan börja med att undersöka ämnet för att sedan utveckla detta genom analys av dess påverkan på samhället och kulturen. Detta kan till exempel ske i form av fallstudier, projekt eller dokumentärer.
2. Man kan utgå från samhällsvetenskapliga, politiska, kulturella eller aktuella frågor som rör ämnet och utveckla detta utifrån dessa frågor, antingen för att få ett svar på frågorna, men kanske mer troligt för att tydliggöra grunden för diskussionen rörande frågorna (mycket i enlighet med emfasen "Science, Technology and Decisions").

Det ska påpekas att "ämne" kan åsyfta både de naturvetenskapliga skolämnena i stort, eller naturvetenskapliga delområden. Vid applikation åsyftas oftast naturvetenskapliga delområden. Det är intressantare att applicera detta arbetssätt på delmoment i fysiken (till exempel radioaktivitet och strålning) än på fysiken i stort, även om det också kan ha sin plats i till exempel en introduktion till fysikämnet. I nästa sektion presenteras delmoment, strukturer, kopplingar och ämnen som är relevanta inom området radioaktivitet och strålning i kursen Fysik 1a.

Det förekommer att lärare samarbetar över ämnesgränser i olika kurser för att skapa dessa bredare perspektiv i undervisningen. Fastän lovvärt, så finns utmaningar med det arbetssättet när man tittar i ett bredare perspektiv. Kopplingen till samhälle och demokratiska värden måste genomsyra arbetet under hela utbildningen och inte enbart de (förmodade) få lektioner under ett läsår där flera lärare lyckas få ihop gemensamma aktiviteter som kan möta målen i respektive kurs. Det kommer följaktligen att ligga på den enskilda läraren i det naturvetenskapliga ämnet att göra de flesta kopplingar under den egna lektionstiden, vilket också samhällsdelen i kursplanen antyder. Det kan tänkas att det ställs orimligt höga krav på lärare i de naturvetenskapliga ämnena om de samtidigt måste fungera som lärare i samhällskunskap, och så kan det vara, men samtidigt existerar inte ämnet ensamt i en bubbla fri från omvärlden. Som lärare får man, och måste man, själv avväga hur djupt man ska, kan och har förmåga att gå i kopplingar till samhället, samt veta varför man gör kopplingarna.

Applikation av Vision II kan göra mycket för att öka intresse och motivation hos eleverna. Detsamma kan också sägas om demonstrationer och laborationer. Som lärare bör man fundera på hur man använder demonstrationer och laborationer i sin undervisning. Många kan fastna i "Scientific Skill Development" emfasen och tänka att processen alltid är i centrum, men möjligheten att öka elevernas intresse och motivation finns också, och bör därför beaktas. De bästa laborationerna är förmodligen sådana där eleverna kan se det intressanta, eller kanske tillochmed det "häftiga", i ämnet samtidigt som de utvecklar vetenskapliga färdigheter. När det gäller demonstrationer så kan man väl argumentera att hela syftet är att föda intresse och synliggöra naturvetenskapliga processer, och detta behövs väl alltid.

Exempel på moment, kopplingar och innehåll

I denna sektion följer fem tabeller som utforskar kopplingar mellan de tre huvudområdena ämne, samhälle och populärkultur, för ämnet radioaktivitet och strålning. De tre första tabellerna presenterar innehåll för de tre huvudområdena, och de två sista presenterar kopplingar mellan dessa områden. Kopplingarna som presenteras i tabellerna är inte på något sätt fullständiga sammanställningar av alla kopplingar som kan göras, men de utgör konkreta och ofta mycket aktuella kopplingar inom sammanhanget och ramen för ämnesområdet och kursen Fysik 1a i helhet. Ämnesinnehållet styrs av Skolverket genom kursplanen (Appendix B), men det finns relativt mycket frihet att som lärare bestämma hur mycket man ska fördjupa sig i varje ämnesområde. Följande lista är ett grovt exempel på innehåll som följer kursplanen.

Ämne	
Kategori	**Innehåll**
Strålning	Alfa-, beta- och gamma-strålning.
Strålkällor	Uran och andra instabila nukleider.
Ljus och dess egenskaper	Våg och partikelegenskaper, energi- och frekvenssamband.
Halveringstid, livstid och aktivitet	Halveringstid, livstid, aktivitet, enheter, skillnader i tider för olika strålkällor.
Dos, effektiv dos och enheter	Dos, effektiv dos, enheter, energideposition och jonisering.
Strålningens penetrationsförmåga	Penetrationsförmåga hos alfa-, beta- och gammastrålning.
Bakgrundsstrålning	Kosmisk strålning, Uran i berggrunden, Radon i byggnader.
Strålning i medicin	Röntgen och andra avbildningstekniker, Cancerbehandling.
Strålsäkerhet	Försiktighetsåtgärder för att skydda mot strålning.

Ämnet radioaktivitet och strålning återfinns i många delar av samhället och antalet paralleller som kan dras begränsas sannolikt till störst del av den enskilda lärarens kreativitet. I följande tabell listas sammanhang med starka kopplingar till det aktuella ämnet. Vad dessa kopplingar är lämnas till läsaren, men ledning finns i den tes som utgör källan till denna guide.

Samhälle	
Kategori	**Innehåll**
Historia	• Henri Becquerel. • Paret Curie. • Kunskapsutveckling i ämnet. • Användning i teknik.

Kärnvapen	• Hiroshima och Nagasaki
	  ○ Historia (effekt på befolkningen).
	  ○ Oro och skapandet av helvetet på jorden.
	  ○ Sjukdom och återhämtning.
	• Kärnvapentest och bakgrundsstrålning.
	• Radioaktivt nedfall.

Kärnkraft och kärnavfall	• Kärnkraftens funktion. • Kärnavfall och förvaring.
Kärnkraftsolyckor	• Tjernobyl. • Fukushima. • Three Mile Island.
Åldersbestämning	• Kol-14 och andra liknande metoder.
Strålning i medicin	• Röntgen och andra avbildningstekniker. • Cancerbehandling.
Strålning och sjukdom	• Strålsjuka. • Cancer. • Risk och strålningsmängd.
Rädsla samt stigmatisering av människor och områden	• Olycka i Brasilien där människor kom i nära kontakt med medicinskt kärnavfall [17]. • Fukushima och Tjernobyl idag. • Dödsfall vid evakuering av Fukushima. • Oskäligt höga kostnader per levnadsår för skyddsåtgärder inom kärnkraft [17].
Bakgrundsstrålning och radon i hemmet	• Kosmisk strålning. • Uran i berggrunden. • Radon i byggnader. • Kärnvapentest.

Radioaktivitet och strålning återfinns även i en bred omfattning i populärkulturen, och även här så ligger den största begränsningen i mängden kopplingar som går att göra förmodligen i kreativiteten hos den enskilda läraren. *The University of Alabama in Birmingham* har i projektet *UAB Radiation Pop Culture Project* sammanställt en lista som i skrivande stund innehåller cirka 1000 olika referenser som har gjorts i huvudsak i amerikansk populärkultur [18]. I följande tabell listas några exempel på populärkultur med starka kopplingar till det aktuella ämnet.

Vad dessa kopplingar är lämnas återigen till läsaren, men ledning finns även här i den tes som utgör källan till denna guide.

Populärkultur	
Kategori	**Innehåll**
The Nuclear Power Plant i TV-serien *The Simpsons*	Felaktigheter i den populära TV-serien som gärna driver med människors föreställningar [19].
Godzilla	Japans trauma från atombomberna och hur det återspeglas i Godzilla.
Fantastic Four, Spiderman och andra bestrålade superhjältar	Hur strålningens effekter på kroppen representeras i media.
Muterade djur och mutanter	Ex. treögd fisk i *The Simpsons.*
TV-serien *Chernobyl*	En metafor används där de beskriver strålning "like small bullets", är det en bra beskrivning? Vad skiljer strålning från gevärskulor i hur de orsakar skada?
Datorspelserien *Fallout*	Rädsla för kärnvapen och oro för helvetes-landskap som resultat av kärnvapen.

I tabellen nedan föreslås kopplingar som kan göras till samhälle och populärkultur utifrån det aktuella ämnet.

Kopplingar från Ämne till Samhälle och Populärkultur		
Ämne	**Samhälle**	**Populärkultur**
Strålning	• Sjukdom och sjukvård. • Bakgrundsstrålning. • Strålsäkerhet. • Kärnkraft. • Kärnvapen.	• Metaforen i TV-serien *Chernobyl*. • *The Nuclear Power Plant* i TV-serien *The Simpsons.* • *Godzilla.*

Strålkällor	• Avfallshantering. • Säker förvaring. • Användningsområden för olika strålkällor. • Kärnkraft. • Kärnvapen.	• Metaforen i TV-serien *Chernobyl*. • *The Nuclear Power Plant* i TV-serien *The Simpsons.* • *Godzilla.*
Ljus och dess egenskaper	• Röntgen- och gammastrålning. • UV-strålning från solen.	• Ex. trender i att sola sig brun.
Halveringstid, livstid och aktivitet	• Åldersbestämning. • Radioaktiva utsläpp (ex. Tjernobyl).	• Datorspelserien *Fallout.* • Fiktiva skildringar av efterdyningarna av kärnvapenkrig och liknande.
Bakgrundsstrålning	• Radon i hem. • Kosmisk strålning. • Kärnvapen.	• Datorspelserien *Fallout.* • Fiktiva skildringar av efterdyningarna av kärnvapenkrig och liknande.
Dos, effektiv dos och enheter	• Sjukdom och sjukvård. • Källor och doser/aktivitet [20].	• *Godzilla.* • *Fantastic Four, Spiderman* och andra bestrålade superhjältar.
Strålningens penetrationsförmåga	• Sjukdom och sjukvård. • Strålsäkerhet.	• Ex. privata och allmänna bunkrar.
Strålning i medicin	• Sjukdom. • Röntgen och andra avbildningstekniker. • Cancerbehandling. • Stigmatisering.	• *Godzilla.* • *Fantastic Four, Spiderman* och andra bestrålade superhjältar. • Japans trauma från atombomberna och hur det återspeglas i Godzilla.

Ur både ett tids-, djup- och omfångsperspektiv så kan det vara relevant att begränsa sig till några få samhällsaspekter med kopplingar till ämnesområdet, vilka kan fördjupas med kopplingar till populärkulturen. I tabellen nedan föreslås kopplingar som kan göras till ämnet och populärkulturen utifrån samhälleliga aspekter. Kopplingarnas exakta dragningar lämnas till läsaren. Eftersom delområdena *strålning*, *strålkällor* samt *ljus och dess egenskaper* är att betrakta som grunden för allt strålningsrelaterat så finnes dessa som koppling till alla relevanta samhälleliga aspekter.

Kopplingar från Samhälle till Ämne och Populärkultur		
Samhälle	**Ämne**	**Populärkultur**
Historia	• Förmodligen hela området utifrån väl vald historiebeskrivning.	• Det mesta som rör radioaktivitet och strålning.
Kärnvapen	• Strålning, Strålkällor och ljus. • Halveringstid, livstid och aktivitet. • Dos, effektiv dos och enheter. • Strålsäkerhet.	• Godzilla. • Datorspelserien *Fallout.* • Filmen *Oppenheimer.*
Kärnkraft och kärnavfall	• Strålning, Strålkällor och ljus. • Halveringstid, livstid och aktivitet. • Strålsäkerhet.	• *The Nuclear Power Plant* i TV-serien *The Simpsons.* • Metaforen i TV-serien *Chernobyl*.
Kärnkraftsolyckor	• Strålning, Strålkällor och ljus. • Halveringstid, livstid och aktivitet. • Strålsäkerhet.	• *The Nuclear Power Plant* i TV-serien *The Simpsons.* • Metaforen i TV-serien *Chernobyl*.
Åldersbestämning	• Strålning, Strålkällor och ljus. • Halveringstid, livstid och aktivitet. • Bakgrundsstrålning.	-

Strålning i medicin	• Strålning, Strålkällor och ljus. • Dos, effektiv dos och enheter. • Strålningens penetrationsförmåga. • Röntgen och andra avbildningstekniker. • Cancerbehandling. • Strålsäkerhet.	• *Fantastic Four, Spiderman* och andra bestrålade superhjältar. • Muterade djur och mutanter.
Strålning och sjukdom	• Strålning, Strålkällor och ljus. • Dos, effektiv dos och enheter. • Strålsäkerhet.	• *Fantastic Four, Spiderman* och andra bestrålade superhjältar. • Muterade djur och mutanter.
Rädsla samt stigmatisering av människor och områden	• Strålning, Strålkällor och ljus. • Strålsäkerhet. • Dos, effektiv dos och enheter. • Bakgrundsstrålning.	• Godzilla. • Datorspelserien *Fallout.*
Bakgrundsstrålning och radon i hemmet	• Strålning, Strålkällor och ljus. • Strålsäkerhet. • Dos, effektiv dos och enheter. • Bakgrundsstrålning.	• Datorspelserien *Fallout.*

Delar, moment och strukturer

I lektionsplaneringen kan man strukturera hela eller delar av området på olika sätt. Hellre än att gå den enkla vägen och bara kryssa av en sak i taget så kan man dela upp området i flera delområden som behandlar närliggande koncept. Dessa kan återanknyta till varandra och samma samhälls- och kulturkopplingar kan användas för att expandera flera koncept. I exempelplaneringen i Appendix A så har ämnesområdet delats upp i delområdena *Strålning och strålkällor, Strålning i medicin* och *Strålningen runt omkring oss.*

En annan strukturform, som även kan integreras med delområdesuppdelningen, är att sätta ämnet i kontext genom att utgå från en historiebeskrivning, alternativt en samhälls- eller populärkultursbeskrivning, och utveckla området inom kontexten för beskrivningen. I exempelplaneringen sätts området *Strålning och strålkällor* i kontexten av en historiebeskrivning av Tjernobylolyckan.

En tredje strukturform, som även den kan integreras väl med delområdes-uppdelningen, är att inleda varje nytt område med en laboration/demonstration som relaterar, förankrar och bygger grund för det kommande området, vilket även det exemplifieras i exempelplaneringen. Det finns dock inget som hindrar att på liknande sätt i stället placera laborationen/demonstrationen någon annanstans inom delmomenten och använda upplevelsen för att förstärka teorin.

Avslutande tankar

Som lärare kan brist på undervisningstimmar och tid för planering leda till att kopplingen mellan ämnet och världen utanför klassrummet hamnar i skymundan för att ge mer tid åt ämnets vetenskapliga kärna. En tillbakagång till Vision I. Förhoppningen med denna guide är att den ska förenkla den enskilda lärarens arbete samt inspirera till att ta steget in i Vision II, genom de didaktiska argument som förts fram i detta dokument, men även som en väg att möta de relativt omfattande mål om demokrati och samhällskoppling som satts upp i läroplanen och kursplanen.

Det kan tänkas att vissa ämnen är svårare att koppla till samhället och populärkulturen än andra. Ämnen som är mycket teoretiska, som kvantmekanik och relativitetsteori känns extra svåra. Men vad de omfattande kopplingar som gjorts i denna guide till det för eleverna abstrakta ämnet *radioaktivitet och strålning* antyder, är att de flesta ämnen förmodligen kan kopplas relativt väl. Detta stämmer högst sannolikt extra väl in på naturvetenskapliga kurser i gymnasiet och grundskolan, som ligger på en relativt låg teoretisk nivå. I fallen kvantmekanik och relativitetsteori, fysikkursernas förmodligen mest elev-frånvända och teoretiska områden, så är det väl även här egentligen relativt enkelt att koppla till kvantdatorer, radioaktiva sönderfall, tidshållning i satelliter och relativ tid för rymdresor nära ljusets hastighet, för att nämna några möjligheter.

Referenser

[1] G. S. Aikenhead, ”Science Education: Border Crossing into the Subculture of Science,” *Studies in Science Education,* vol. 27, nr 1, pp. 1-52, 1996.

[2] Skolverket, ”TIMSS 2019. Svenska grundskoleelevers kunskaper i matematik och naturvetenskap i ett internationellt perspektiv.,” Skolverket, 2020.

[3] P. Nilsson, *Att se helheter i undervisningen – Naturvetenskapligt perspektiv,* skolverket, 2012.

[4] D. A. Roberts, ”Scientific Literacy/Science Literacy,” i *{Handbook of Research on Science Education*, Routledge, 2007, pp. 729-780.

[5] D. A. Roberts, ”Developing the concept of “curriculum emphases” in science education,” *Science Education,* vol. 66, nr 2, pp. 243-260, 1982.

[6] L. J. Rennie, G. Venville och J. Wallace, Learning science in an integrated classroom: Finding balance through theoretical triangulation, Routledge, 2011.

[7] T. G. K. Bryce och E. J. Blown, Ausubel's meaningful learning re-visited, Current Psychology, 2023.

[8] D. Kolb, *Experiential Learning: Experience As The Source Of Learning And Development,* Journal of Business Ethics, 1984.

[9] M. L. Lo, Variation Theory and the Improvement of Teaching and Learning, Acta universitatis Gothoburgensis, 2012.

[10] D. Hebb, The Organization of Behavior : A Neuropsychological Theory., Psychology Press, 2002.

[11] Skolverket, ”Sammanställning och spridning av forskningsresultat,” 2023. [Online]. Available: https://www.skolverket.se/skolutveckling/forskning-och-utvarderingar/sammanstallning-och-spridning-av-forskningsresultat. [Använd 12 03 2024].

[12] J. Biggs, ”Enhancing teaching through constructive alignment,” *Higher Education,* vol. 32, nr 3, pp. 347-364, 1996.

[13] J. Sjöström och I. Eilks, ”Reconsidering Different Visions of Scientific Literacy and Science Education Based on the Concept of Bildung,” i *Cognition, Metacognition, and Culture in STEM Education: Learning, Teaching and Assessment*, Springer International Publishing, 2018, pp. 65-88.

[14] B. Bates, Learning Theories Simplified, Sage Publications, 2023.

[15] I. Abrahams och R. Millar, ”Does Practical Work Really Work? A study of the effectiveness of practical work as a teaching and learning method in school science,” *International Journal of Science Education,* vol. 30, nr 14, pp. 1945--1969, 2008.

[16] B. Lindahl, ”Lust att lära naturvetenskap och teknik? : en longitudinell studie om vägen till gymnasiet,” Acta Universitatis Gothoburgensis, 2003.

[17] P. Slovic, ”The perception gap: Radiation and risk,” *Bulletin of the Atomic Scientists,* vol. 68, nr 3, pp. 67-75, 2012.

[18] The University of Alabama at Birmingham, ”UAB Radiation Pop Culture Project,” [Online]. Available: https://www.uab.edu/shp/cds/health-physics/radiation-pop-culture-project. [Använd 12 03 2024].

[19] Office of Nuclear Energy, ”7 Things The Simpsons Got Wrong About Nuclear,” 2018. [Online]. Available: https://www.energy.gov/ne/articles/7-things-simpsons-got-wrong-about-nuclear. [Använd 12 03 2024].

[20] R. Munroe, ”xkcd,” 12 03 2024. [Online]. Available: https://xkcd.com/radiation/.

[21] K. Yoshinaga, M. Kubota och M. Kamata, ”Simple cloud chambers using a freezing mixture of ice and cooking salt,” IOP Publishing, 2014.

[22] Strålsäkerhetsmyndigheten, ”Att mäta radon,” 2022. [Online]. Available: https://www.stralsakerhetsmyndigheten.se/omraden/radon/att-mata-radon/. [Använd 11 03 2024].

[23] Veritasium, ”The Universe is Hostile to Computers,” 2021. [Online]. Available: https://www.youtube.com/watch?v=AaZ_RSt0KP8. [Använd 11 03 2024].

[24] PBS, ”Uranium: Twisting the Dragon's Tail,” 2015. [Online]. Available: https://www.pbs.org/show/uranium-twisting-dragons-tail/.

Appendix A

Exempel på planering

Del 1 – Strålning och strålkällor

Beskrivning - Explorativ introduktion genom laboration 1. Följande delmoment görs jämsides en historiebeskrivning av olyckan i Tjernobyl ur ett fysiskt och mänskligt perspektiv. (Kort ex. på historieformat: kl 01:23 26 april 1986 sker en explosion i kärnkraftverket nära staden Tjernobyl i nutida Ukraina. Brandmän kommer till platsen för att släcka den resulterande branden, men brandmännen visste inte att det fanns mer än eld och rök på platsen som kunde skada dem… och så vidare.)

Innehåll

1. **Laboration 1: Radioaktiva strålkällor.**

Beskrivning - Se laborationsbeskrivning.

2. Strålning och strålkällor.

Beskrivning – Föreläsning.

3. Halveringstid, livstid och aktivitet.

Beskrivning – Föreläsning. Demonstration med Geigermätare.

4. Kärnkraft och olyckor (Tjernobyl och Fukushima).

Beskrivning - Föreläsning om Fukushima som utökning av Tjernobyl-historien.

5. *The Simpsons* - Felaktig uppfattning om Kärnkraft.

Beskrivning - Elever svarar digitalt på frågor om vad som är missuppfattningen som visas i ett foto/filmklipp ur serien The Simpsons som ofta driver med människors syn på kärnkraft. Svaren visas i diagram för helklass och rätt svar diskuteras.

Del 2 - Medicinsk strålning

Beskrivning - Introduktion genom Laboration 2, där man undersöker penetrationsförmågan hos olika typer av strålning. Följande delmoment genomförs mot bakgrunden av användningen av strålning inom medicin.

Innehåll

1. **Laboration 2: Strålningens penetrationsförmåga**.

Beskrivning - Se laborationsbeskrivning.

2. Strålning i medicin, röntgen och cancerbehandling.

Beskrivning - Föreläsning.

3. "Like bullets" från *Chernobyl*-serien, beskriver verkligheten?

Beskrivning - Exempel från Chernobyl, är det en bra beskrivning?

4. Dos, effektiv dos och enheter.

Beskrivning – Föreläsning.

5. XKCD Infographic om effektiv strålningsmängd (Figur 4).

Beskrivning - Hur stor är strålningsdosen från olika källor? Frågeformulär som styrning? Hur stor dos får eleverna i sig varje år?

6. Påverkan på kroppen och strålsjuka.

Beskrivning - Förklaring av vad som händer med kroppen när den utsätts för olika nivåer av strålning. Möjlig användning av otrevliga bilder på strålsjuka, eller dokumentär om ämnet.

7. Atombomber i Hiroshima och Nagasaki, historia, oro, sjukdom och återhämtning.

Beskrivning - Föreläsning.

8. *Godzilla* i Populärkultur, Japans trauma.

Beskrivning - Föreläsning.

9. Stigmatisering: Fukushima och händelsen i Brasilien [17].

Beskrivning - Föreläsning.

Del 3 - Strålningen omkring oss

Beskrivning - Introduktion genom Laboration 3, där bara bakgrundsstrålningen är i fokus. Delmomenten trycker på sådant som är i elevernas omgivning. Här kan man också, vilket har gjorts, trycka in Dimkammarens historia och funktion som samhällskoppling.

Innehåll

1. Dimkammarens historia och funktion.

Beskrivning - Föreläsning, bilder och film från laboration.

2. **Laboration 3: Bakgrundsstrålning.**

Beskrivning - Se laborationsbeskrivning.

3. Bakgrundsstrålning, kosmiska strålar, Radon och Uran i berggrunden, utspädning som koncept.

Beskrivning - Föreläsning, kanske demonstration med granit och Geigermätare.

4. Okunskap om Radonets existens och påverkan på hälsan.

Beskrivning - Föreläsning + Hemuppgift att gå hem och ta reda på om en mätning har gjorts där de bor och vad resultatet var.

5. *Fantastic Four* och andra strålnings-hjältar i Populärkultur.

Beskrivning - Föreläsning, Vidareutveckling av kosmisk strålning och strålning i allmänhet och hur den representeras i kulturen.

6. Bakgrundsstrålning från atombombstester.

Beskrivning - Föreläsning.

7. Strålsäkerhet.

Beskrivning - Föreläsning (Vidareutveckling av vad eleverna får lära sig i samband med laborationerna).

8. Avslutning med resultatet från elevernas Radonundersökning hemma.

Beskrivning - Resultat och diskussion om elevernas Radonundersökning hemma.

Beskrivning av Laborationer/Demonstrationer

Här presenteras tre laborationer/demonstrationer där strålning görs synligt för eleverna genom användandet av dimkammare. Dessa kan byggas på mer eller mindre avancerade vis, till exempel genom användandet av kolsyreis, värmepumpar, peltierelement eller saltblandat vatten fryst i en vanlig frys. En enkel design som använder saltblandad is finns länkad här, och finns även att hitta bland referenserna för denna guide [21]. Med en uppsättning dimkammare stor nog så kan eleverna i grupper genomföra följande laborationsförslag som laborationer, men det går även att genomföra dessa som demonstrationer med endast en dimkammare givet att synligheten för eleverna är god nog.

Laboration 1: Radioaktiva strålkällor.
Beskrivning - Strålkällor placeras i dimkammare och man kan se de olika partikel-banorna från olika sorters strålning.

Laboration 2: Strålningens penetration.
Beskrivning - Hållare med en pappersbit och en bit aluminiumplåt placeras i dimkammaren på var sin sida om en strålkälla. Elever kan se hur vissa partiklar går igenom papperet/aluminium-biten och andra inte.

Laboration 3: Bakgrundsstrålning.
Beskrivning - Ingen strålkälla placeras i dimkammaren. Istället får eleverna se om de ser något ändå, vilket kommer vara bakgrundsstrålning i form av alfa-, beta- och gammastrålning, men även i sällsynta fall muoner som kommer från övre atmosfären som biprodukter av interaktioner mellan atmosfären och kosmisk strålning.

De tre laborationerna kan slås ihop till en större laboration, men dimkammare som kyls med saltblandad is har en relativt kort funktionstid innan de blir för varma i rumstemperatur, vilket begränsar tiden för laborationen [21]. Lyckade uppställningar kan uppvisa bilder som den som visas i Figur 3, där man kan se streck av kondensering från alfa- (det tjocka sträcket) och betastrålning (de tunna strecken). Laborationerna kräver arbete med strålkällor. Gymnasieelever får handskas med dessa under handledning av lärare. De strålkällor som får användas i skolor är relativt ofarliga, men försiktighetsåtgärder bör ändå antas. Här länkas en affisch från strålskyddsmyndigheten om hur man arbetar säkert med strålkällor, men se även deras hemsida och gällande dokument.

Figur 3: *Strålbanor av alfa- och betastrålning i dimkammare. https://commons.wikimedia.org/wiki/File:Nebelkammer-LMU-1.jpg*

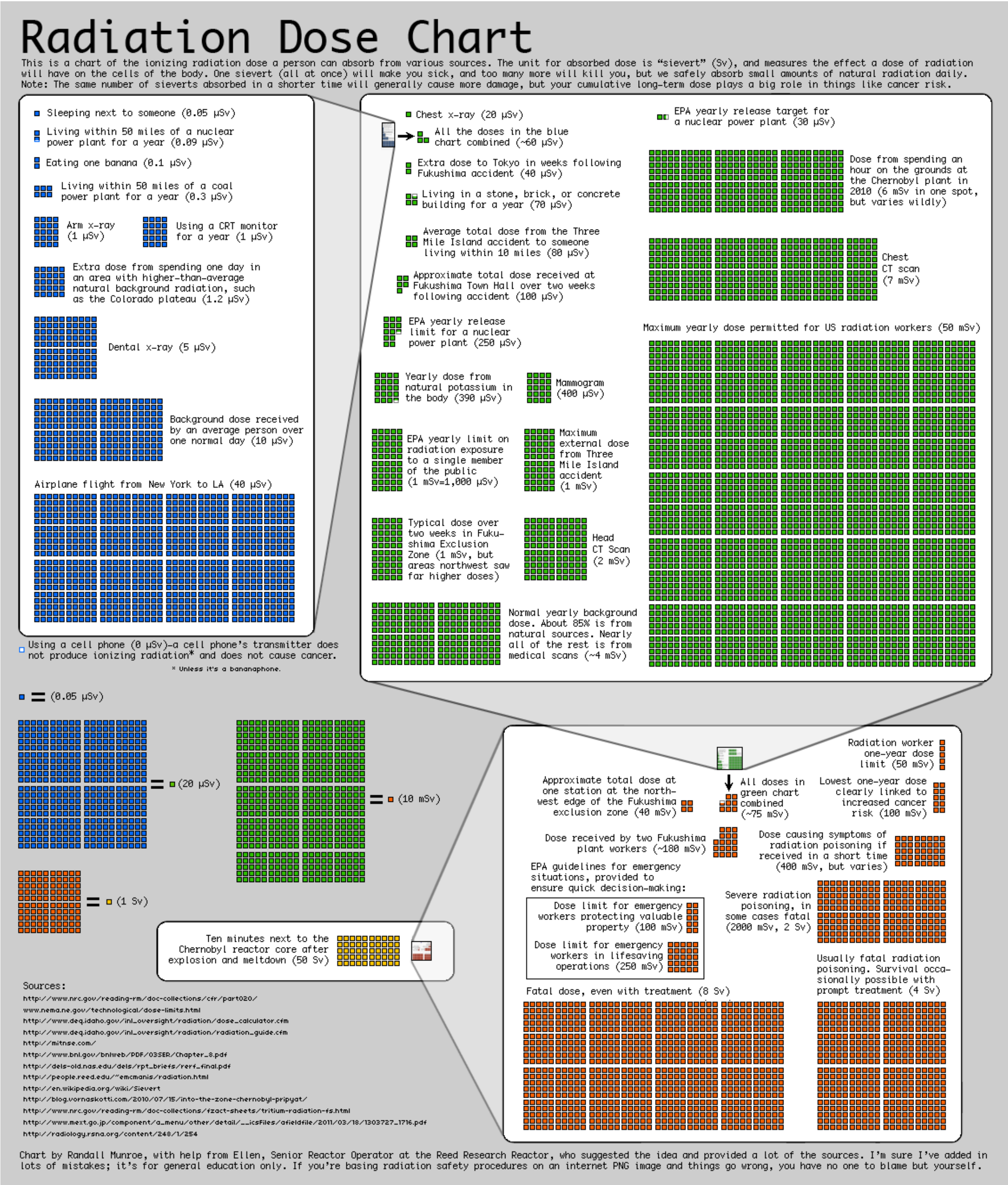
Uppgifter och aktiviteter

Här följer några förslag/exempel på aktiviteter och uppgifter som kan användas i undervisning inom området.

Hemuppgift Radon - Eleverna undersöker med vårdnadshavare/hyresvärd/bostadsrättsförening om en radonmätning har gjorts där de bor, och om det har gjorts, vad resultatet blev. Uppgiften är utformad mot bakgrunden att Strålsäkerhetsmyndigheten uppskattar att det finns cirka 400 000 bostäder i Sverige som har högre radonhalt än det godtagbara referensvärdet [22].

Dokumentären "The Universe is Hostile to Computers" [23] – Dokumentär i kortformat av Youtubekanalen *Veritasium* som är en av Youtubes största utbildningskanaler. Den handlar om hur strålning, men framför allt kosmisk strålning, kan påverka datorer. Dokumentären utgår från en historisk och samhällsvetenskaplig kontext, liksom kanalens andra dokumentärer. Dokumentären gör sig troligen extra bra med elever i Teknikprogrammet. För den intresserade finns det även en dokumentärserie i tre delar från 2015, med kanalens grundare som programledare, som utreder Uranets historia och plats i samhället, med titeln *Uranium: Twisting The Dragon's Tail* [24].

XKCD:s Infographic om effektiv strålningsmängd [20] – Eleverna får undersöka radiologiska risker i vardagen genom att konsultera XKCD:s Infographic om effektiv strålmängd som visas i Figur 4. Ett sätt att styra eleverna rätt vore att använda ett frågeformulär som frågade om till exempel relationer i storlek mellan olika källor, totala doser för en samling aktiviteter, eller dosgränser. Exempelfråga: hur många gånger behöver man flyga mellan New York och Los Angeles för att nå den årliga maxdosen för amerikanska arbetare? Hinner man det?



***Figur 4**: Infographic om storleken på strålningsdoser och deras påverkan på kroppen [20].*

Appendix B

Aktuella delar av Skolverkets mål och centrala innehåll för Fysik 1a

Undervisningen i ämnet fysik ska ge eleverna förutsättningar att utveckla följande:

- Kunskaper om fysikens begrepp, modeller, teorier och arbetsmetoder samt förståelse av hur dessa utvecklas.
- Kunskaper om fysikens betydelse för individ och samhälle.
- Förmåga att använda kunskaper i fysik för att kommunicera samt för att granska och använda information.

Centralt innehåll - strålning inom medicin och teknik

- Radioaktivt sönderfall, joniserande strålning, partikelstrålning, halveringstid och aktivitet.
- Orientering om elektromagnetisk strålning och ljusets partikelegenskaper.
- Växelverkan mellan olika typer av strålning och biologiska system, absorberad och ekvivalent dos. Strålsäkerhet.
- Tillämpningar inom medicin och teknik.

Centralt innehåll - fysikens karaktär, arbetssätt och matematiska metoder

- Ställningstaganden i samhällsfrågor utifrån fysikaliska förklaringsmodeller, till exempel frågor om hållbar utveckling.

DEPARTMENT OF COMMUNICATION AND LEARNING IN SCIENCE
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden
www.chalmers.se

CHALMERS
UNIVERSITY OF TECHNOLOGY