CHALMERS
UNIVERSITY OF TECHNOLOGY

Radio lab

Application of variation theory in secondary school science and technology instructional design

Omid Fassihi Karimi

Master thesis in
Communication and learning in science
Gothenburg, Sweden, 2021

Title:
Radio lab

Author:
Omid Fassihi Karimi

Supervisor:
Jens Kabo

Department:
Communication and Learning in Science
Chalmers University of Technology
SE-412 96 Göteborg
Sweden

Acknowledgements

I would like to express my sincerest gratitude towards my supervisor Jens Kabo for his unwavering support and encouragement in completing the project through so many unforeseen and unfavourable circumstances. I also want to pay my regards to my examiner Samuel Bengmark for his role in providing guidance and helpful input but also for his many years as the most friendly and bright head of any masters programme I could've imagined. I should also thank the two participants that risked their health to assist in the work. Last but not least, I would like to send my special regards to all my friends and family who not only offered their insights but also welcome distractions when needed.

Abstract

This master thesis reports on the process of designing a lesson plan which aims at teaching secondary school students of science and technology the mechanisms of electromagnetism by means of supervised construction of a crystal radio model. Variation theory is chosen as the main theoretical framework and the thesis contains descriptions of the theory's main postulations and how they inform the design choices made. Attempts to evaluate the lesson plan were made by means of a simulated lesson where prospective secondary school teachers of science and technology participate as students. The participants were interviewed to document their experience to subsequently attempt to evaluate the lesson design.

Table of contents

Introduction

Background & Motivation
The understanding and description of physical phenomena is an endeavour which has captured the human imagination for all of known history. Despite the lengthy history of science as a field, the field of science education research is relatively new. Andersson (2000) defines science education research as the creation and development of knowledge regarding teaching content and different modes of teaching.

Before the 1960's the United States was the only country where research into science education was being conducted (Fensham, 2003). The field has since grown immensely and in the last twenty years it is regarded as its own area of research. According to Fensham (2003) some of the hallmarks of science education research are the concerns with students' and teachers' perceptions of phenomenon, teaching content and execution. The concern for perceptions is an attribute of a branch of education research referred to as phenomenography, which in turn laid the foundation for the theory of learning named 'variation theory'.

Science education research has been carried out regarding teaching specific topics, but the concept of electromagnetism as a teaching subject is currently relatively underexplored compared to other topics in physics. Some studies exist (Michelini, 2007; Bagno, 1998; Thong, 2008; Guisasola, 2004) most of which are concerned with how the subject is taught at the undergraduate level. Some of these studies however state the need for exploration into how the subject is taught at earlier levels of schooling. Michelini et. al. (2007) described some common misconceptions students held in regards to the topic. They also come to the conclusion that teaching in science benefits from being centered around concrete problems and how students conceptualise these. Furthermore, at the time of writing this thesis there was only one study found where variation theory exclusively is used as a framework to study learning within physics, and is used to study learners' interactions with physics software (Euler, 2020).

In light of this, this thesis is concerned with prospective secondary school science teachers' perceptions of electromagnetism and the design of a teaching activity that can facilitate the effective conceptualisation of this phenomenon. The work follows the guidelines made by Lo (2012) for conducting a *lesson study*, although due to the coronavirus pandemic only the early steps of the entire cycle were possible to complete. It also incorporated the tried and proven principles of variation theory developed by Marton & Booth in the lesson design (Lo, 2012). The result of this work may influence teaching in the subject through descriptions of successful teaching strategies and methods for the subject matter in question.

Some argue that the most important aspect of science education research is its ability to develop teaching praxis through implementation of its results in education policy (Jenkins, 2001). This thesis is instead focused on implementation at the classroom level, more specifically on the design of lesson activities involving practical elements and their theoretical grounds. The reasoning stems from the potential for practical elements to facilitate discourse which will foster students in what Schoultz (2001) refers to as a discursive tradition. The claim is that by appropriating a certain type of discourse, scientific reasoning is developed. This is in line with findings which suggest that discussion of topics between students leads to successful teaching in science (Solomon, 1998; Ritchie & Tobin, 2001).

According to Leach & Scott (2003) scientific knowledge is constructed in the mind of the learner as a result of interaction with objects or cultural products in a social setting. By confronting students with the task of assembling a model system designed to utilize a natural phenomenon they will be forced to consider their own mental models of how the system responds to inputs from its surroundings. The learner only internalizes the conceptual tools presented after their meanings are repeated on the “intermental plane” and reformed in the “intramental plane”. Sweller (1988) refers to this processing in the intermental plane as cognitive load on the working memory. By putting the explicative burden on the learner they are forced to undergo this process while receiving feedback on their reasoning.

However, this is not sufficient. In order for a change in conceptualisation to occur successfully the learner must also be made aware of this change in perception (Vosnia-dou & Ioannides, 1998). This means a teacher must be aware of the students' reasoning in the topics taught if he or she aims for a change in the conceptualisation of his or her students. This also calls for the consideration of meta-cognitive aspects in any lesson design aiming to achieve this.

Learning in science is widely modeled as the change of conceptualisation in the learner, preferably in a way that is consistent with the teacher's way of conceptualising the teaching topics. Variation theory gives tools with which the phenomena that are considered in science education can be analysed. Even though the lesson design will be centered around a practical problem the emphasis of the thesis will be both on the theoretical aspects of the teaching of the particular content and the content itself. This is supported by findings which suggest that practical work in isolation is not effective in learning and that other factors such as instructional design have a greater impact on learning (Abrahams & Millar, 2008).

Research question

The aim of this thesis is two-fold which is reflected by the research questions posed. Firstly the object of questions 1 and 2 is to answer how to design a lesson regarding the topic of electromagnetism relevant to the radios function according to the principles of variation theory. Secondly, the third question reflects an attempt to evaluate the design decisions. The results might predict if the lesson can bring about conceptual change in groups of learners, and might be of use in teaching practice or for further validation.

The purpose of the lesson is to teach some principles of electromagnetism by also incorporating a practical element which will be for the students to construct a simple model of a resonating circuit or a ‘crystal radio’. The design will also consider how students best should be instructed through the practical part of the lesson.

Formulated more precisely with terms used within variation theory the questions are as follows:

1. What are the critical aspects within electromagnetism necessary to understand the function and significance of the radio as a technical solution?
2. What patterns of variation can be utilized to facilitate the discernment of the aforementioned aspects and how should the patterns be designed?
3. How are the proposed patterns of variation experienced by prospective secondary school teachers of the technology subject from an implementation perspective?

Theoretical frameworks

The main parts of the project are concerned with many aspects of variation theory, an overview of the theory and the aspects of the theory that are implemented in the design are introduced in this section. The section concludes with a description of the lesson activities.

Variation theory
Variation theory is a theory of learning which was conceived as a result of the rise of phenomenography as a field of research. Phenomenography is a philosophical and methodological branch of science concerned with the qualitative differences in the perception of phenomenon (Marton & Booth, 1997; 2000). These differences are found in how the perception is structured, which aspects and parts it contains and their relation in regards to each other and the whole. Perception is also limited, meaning there can only be so much in focus at one moment in time.

Critical aspects
The core of variation theory is that learning is a result of a change of perception of the critical aspects of an object of learning. For this change to occur the learner must discern the critical aspect being presented. Critical aspects can be considered ‘values’ on what is referred to as different ‘dimensions of variation’. For instance, ‘meowing’ is a value on the dimension of ‘animal calls’ which distinguishes a cat from a dog. Critical aspects as such are what separates the object of learning from similar objects and is what is most fundamental to that object (Lo, 2012). The object of learning is the concept or phenomenon that the educator wishes to teach to his or her students. The theory puts emphasis on the importance of analyzing the object of learning to identify the critical aspects but also how to make them discernable and adjust its presentation to the preconceived notions of the learner. It also defines learning as becoming able to recognize and describe the phenomena being studied as values on specific dimensions of variation. In the context of the study conducted by Euler et. al. (2020), a student is regarded as proficient when he or she can independently identify the mechanisms (dimensions of variation) that govern the behaviour of a simulated physical system. In essence, to be able to distinguish an object from a closely related object is regarded as the fundamental first step towards mastery of any topic.

Variation theory is based on the theorized ‘structure of awareness’ of phenomenography which states that the mind is only capable of focusing on limited aspects of an object at a time. Accordingly an increase in the aspects one can simultaneously discern from an object is equivalent to a greater understanding of that object. Furthermore this focus creates a divide between the so called external and internal ‘horizon’ of the object.

Structure of object of learning

The internal horizon contains the critical aspects and their relations which define the object. These relations are what gives the object its structure and is what in turn gives meaning to an object. According to Marton and Booth (1997, p. 87-88) structure and meaning are closely related and are discerned simultaneously and dependently of each other. The external horizon contains aspects which are closely related to the object in focus but rather define the context in which the object resides. (Lo, 2012). From the ‘external horizon’ the focus then is broadened towards the so called ‘margin’ which contains less closely related aspects.

Patterns of variation

In order for a critical aspect to be discerned in a lesson setting, a pattern of variation must be presented. The patterns of variation include contrast, separation, generalisation, and fusion (Lo, 2012).

Contrast entails presenting the object of learning in conjunction with a similar object that only differs in the critical aspect which is to be discerned. If the similar object is familiar to the learner or is related to his or her preexisting notions, the difference becomes apparent and acts as a starting point for the learner to begin forming a new concept. This has been proven to lead to a greater chance for the critical aspect to be discerned and consequently to a more lasting impact from the lesson activity.

To understand this further one can consider the following thought experiment: an individual who is only familiar with dogs is presented with a cat. One can assume such an individual would at first be struck by all the similarities the cat shares with the dogs previously experienced and incorrectly identify the cat as a dog. A way to teach the concept of a cat is to focus on that which distinguishes it from the dog. For instance, when the cat is approached it might meow. When this happens, a contrast emerges and the critical aspect ‘type of call’ can be discerned which can be used to distinguish the objects cat and dog.

Separation is the cognitive process in which the learner is aware of the part-whole relationship within the object of learning or between the object of learning and its margin and distinguishes them. In the previous example separation would be the process where ‘meowing’ is separated from the cat and considered in the dimension ‘animal calls’ next to the dogs ‘bark’.

Separation is similar to *generalisation* so far as it entails separating aspects, the difference is that generalisation is the process of separating non-critical aspects. For instance, by introducing more examples of furred animals the aspect ‘furred’ becomes separated and can be deemed non-critical.

When an object of learning requires the discernment of several critical aspects *simultaneously, the* pattern of variation that facilitates this is referred to as *fusion*. According to variation theory, learning is the process of discerning and relating several aspects simultaneously. When we ask our hypothetical individual to describe his or her newly formed concept of a cat this is what is desired. That is for the individual to simultaneously recognize the part-whole relationship which is shared between the cat and the dog (furred, four-legged) and that which is distinct (bark or meow).

It is at these parts of any lesson in which the learner is most challenged. This since the load on the working memory is highest when trying to connect previously unfamiliar concepts. However when these connections are made and the learner can be made aware of these aspects and their relations is when learning has taken place. This in the sense of mastering independently reasoning in a desired manner.

Recommended lesson sequence
The recommended teaching sequence as described by Marton in a 2009 lecture (Lo, 2012, p. 102) is as follows:

1. The introduction of the undivided whole (fusion)
2. Contrast (separation of critical aspects from the whole)
3. Generalisation (distinguishing critical aspects from non-critical ones)
4. Presenting the critical aspects in relation to each other and the whole (fusion)

Relevance structure and motivation
The aspects one can discern from an object of learning also depends on how the lesson activity refers to the preexisting experiences, attitudes and understanding of the topic the learner has. The way in which the critical aspects and their relations between internal and external horizon are defined and presented is referred to as ‘relevance structure’. This is deemed of great importance for effective learning. (Lo, 2012). This is also called ‘ways of seeing’ because it is how objects are experienced by those who study and understand them. In order for the learner to adopt a relevance structure it must be deemed relevant for the students to feel motivated to learn.

There are a multitude of studies which have shown a declining interest in science as a subject, one of the reasons being that the subject doesn’t feel relevant to the learners, their everyday lives and the society in which they reside. (Dillon, 2009; Gilbert, 2006; Holbrook, 2008). A way of combating this has been including more humanistic and societal perspectives in science and technology education. The curriculum for the course even emphasizes the interaction between technology and society in their respective development (Skolverket, 2020). This, in theory, gives the lessons a greater chance of invoking interest in a broader group of students, namely those who are more interested in how technology and science as a factor in how society has developed and how that development will continue or be altered.

The initial introduction of the undivided whole in a lesson sequence is according to Marton (2006) not for discernment of critical aspects but rather to introduce a relevance structure from which discernment is possible but also gives weight and relevance to the subject presented.

In order for learning to occur the critical aspects not only need to be presented with a suitable pattern of variation, they must also be presented in a way that takes into consideration the often faulty preconceived notions of the learner. Studies into teaching electromagnetism have shown that learners often struggle with basic concepts such as charge. (Michelini, 2007; Thong, 2008). Common errors are for instance the notion that a charge only produces an electric field, and that a current only produces a magnetic field. (Bagno, 1998). They also have difficulties describing the reciprocal relation between electric and magnetic field, stating that a changing magnetic field induces an electric field but failing to state that the reverse is also true. It has also been shown that a large portion of learners thought that a charge at rest produces both an electric and magnetic field. (Guisasola, 2004).

This is why the initial stage of the lesson is of such great importance because it is where the teacher has the possibility to gauge which misconceptions the students harbour and can adjust the planned lesson sequence in order to attempt to correct them. Lo (2012) describes many situations where such preconceived notions are resolved at a meta-level and also emphasizes the need for the teaching of meta-knowledge and metacognitive strategies. This is in line with the findings presented previously which show that the reasoning behind the concepts being taught have to be made explicit and explained for teaching to be effective (Vosnia-dou & Ioannides, 1998; Lo, 2012).

Cognitive load and instructional design

A consideration that must be made in any lesson design is both the quality and the amount of content that students can process in a given lesson. One explanation for students failing to learn the concepts being taught is that there are too many aspects presented at once, or that the presentation requires a great amount of interpretation. This is referred to as *extraneous load,* as opposed to *intrinsic load* which is the cognitive load from transferring topical knowledge from working memory to long-term memory. The knowledge formed in the long-term memory is said to be grouped into *schemas*. (Sweller, 1988). How much cognitive load a learner experiences is highly individual and is dependent upon many different factors, but is nonetheless an important factor to consider in lesson design.

Goal setting

One of the goals of the lesson activity is to develop a generic capability, to be able to recognize a hierarchical system structure in a technical solution. According to Marton and Tsui (2004) these capabilities are developed through studying specific content related to such capabilities. Furthermore, the goals should also be clear and observable. (Felder & Brandt, 2016). That the capabilities that the teacher wishes to develop in his or her students are stated clearly means that they can be easily understood by the students. Observable means that it is possible for the students to demonstrate these capabilities and their aptitude be evaluated.

Electromagnetism and the crystal radio

The aspects of the physical phenomena and the construction in which the lesson activity is concerned with is introduced in this section.

The radio as a technical solution utilizes the fact discovered by Scottish physicist James Clerk Maxwell (1831-1871). The fact was that a change in electric field induces a perpendicular magnetic field and vice versa (Petruzellis, 2002). This mechanism is what gives rise to what is known as an electromagnetic wave. The changes in the fields affect each other and allow the wave to propagate. The radio's commercialisation is attributed to Italian scientist Marconi (1874-1937) and the equipment being produced gave rise to the broadcasting industry.

According to Michelini et al. (2007) the main conceptual referent used for understanding electromagnetism is attraction. The concept of attraction is general to many physical phenomena and its intuitiveness lends a great entry into explaining electromagnetism. Since gravitational attraction is something commonly experienced in everyday life it is effective as an analog for the attraction between magnetic poles. According to variation theory this strengthens the understanding since it provides a conceptual anchor, a connection between an aspect within the radio's internal horizon and concepts which exist in its margin. Furthermore, it gives an opportunity for learners to equip themselves with physics terms to enable them to explain the function of the radio in a formal manner.

The radio is a solution part of a greater technical system. From a broadcasting station a varying current is run through a broadcasting antenna which induces a varying magnetic field (Wulff, 2019). This constitutes the broadcasting signal or carrier wave which the receiving antenna is to detect. The detection of the broadcasted signal works by the inverse of the mechanism which induced the signal, namely that an electromagnetic wave will induce a varying current with the same frequency in a conducting material.

In order for a receiver to distinguish one signal from many that are broadcasted simultaneously some form of modulation must be used. The signals that the simple crystal radio is designed to detect uses AM or amplitude modulation (Petruzellis, 2002; Wulff, 2019). This is a form of modulation in which the amplitude of the carrier wave is varied according to the amplitude of the audio signal which is to be received.

Implementation: theory-informed lesson design

How the theoretical framework is implemented in the lesson design and further motivations for the decisions made are described in the following section.

Modelling the object of learning
The simple crystal radio, hereafter referred to as the crystal radio, is a model chosen for its simple construction. The materials needed for its construction are affordable and commonly available, and its construction is safe and straightforward making it suitable for a classroom setting.

The reason the crystal radio can be simple in construction is since the carrier wave it is designed to detect doesn't vary in frequency. It only detects a specific frequency by utilizing a resonating circuit with a mechanism that allows the resonating frequency to be set by the user. The design used for this study is shown schematically in figure 1. The tuning cable is what allows the user to set the number of loops in the coil by closing the circuit at different parts of the coil. This gives the model the ability to have its resonating frequency adjusted and the model to detect different frequencies.

Traditionally a resonating circuit also needs a capacitive component for charge to gather (Petruzellis, 2002). This model only has the inductive element of the circuit and utilizes the so-called parasitic capacitance in the coils in order to achieve resonance. It is therefore simpler in construction and the lesson design can also be made simpler as a result. However this limits the frequency range that the model can detect and can make tuning the coil difficult.

When the crystal radio detects a wave from an AM-broadcasting station this essentially means that the wave induces a surge of current in the circuit. Due to the positive charge inherent in the membrane in the earpiece this in turn causes a displacement which in turn causes a displacement in the air in contact with the membrane. This ultimately causes a soundwave, which can be detected by the user and aid him or her in tuning the circuit to the frequency of a nearby broadcasting signal.

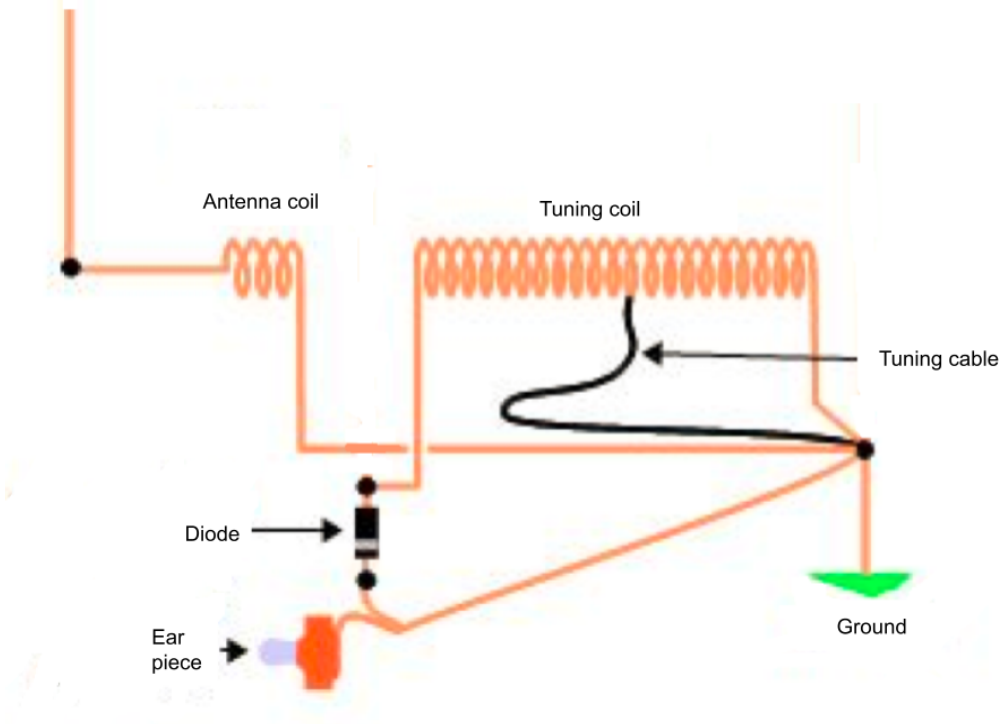


Figure 1: Approximate circuit schematic for simple crystal radio model.

Structuring object of learning

In order to successfully design an effective lesson the object of learning is subjected to a methodological reductive analysis (Ruse, 2005). Within this framework, the radio as a phenomenon can also be regarded as an object consisting of separate entities. Subsequently the radio is boiled down to it's most critical components. This in turn gives which critical aspects need to be discerned to understand their function. This reasoning is then applied for each part identified to in turn be able to discern and describe the phenomena it utilizes to serve its purpose. The analysis can be said to be made using the author's own technological expertise but was also informed by some literature on the specific subject (Wulff, 2019).

Since the radio, as all technical solutions, has a system structure, with subsystems and their interdependence, its internal horizon is straightforward to outline and can be seen in Figure 2. The critical components and the mechanisms by which they operate are identified and described but also their interaction and interdependence. What is notable here is the inclusion of related means of communication. These are used to generalise the concept of electromagnetism as a means of communication which in turn puts into focus specifically how the radio manages this. How the object of learning is structured for the lesson activity is of importance for how the learning objectives for the lesson are formulated.

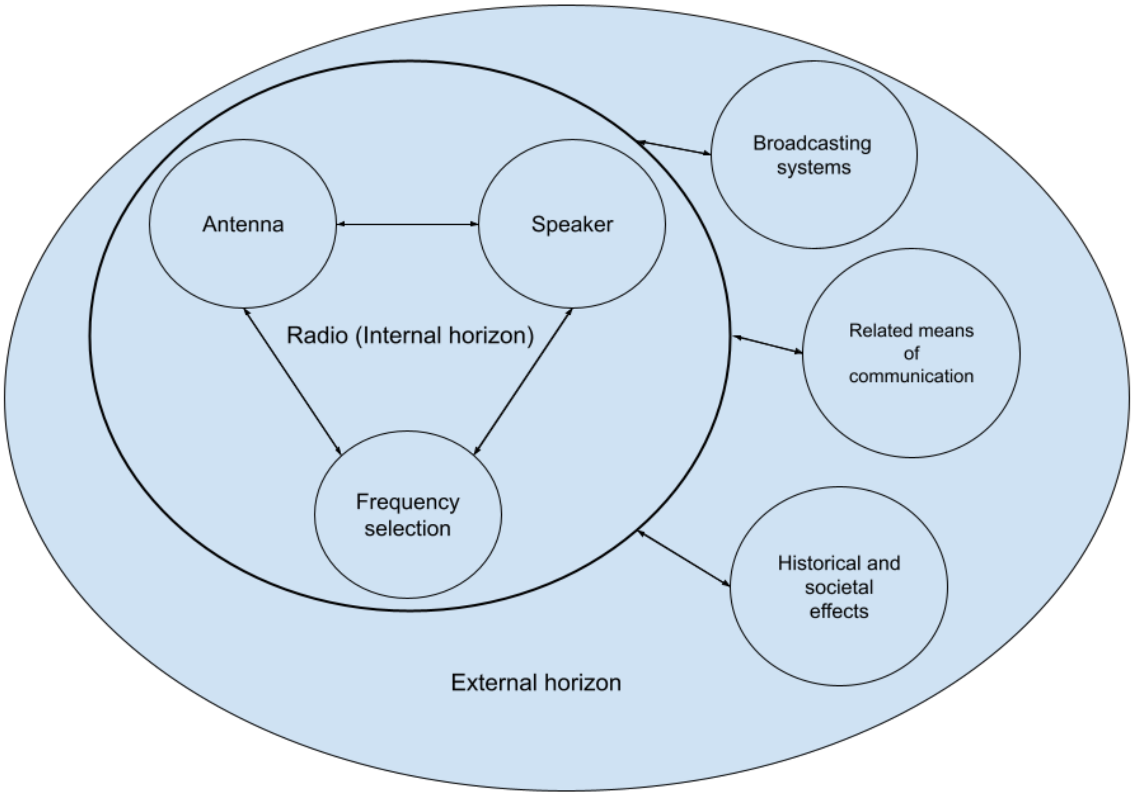


Figure 2: Diagram of how the lessons object of learning is structured

A.	Has an antenna in which a current is induced by an **electromagnetic wave,** a signal
B.	Decodes electromagnetic signal from broadcasting antenna into a **soundwave**
C.	Can be calibrated to decode a specific signal in a spectrum of signals
D.	Had a substantial societal impact through large scale commercialisation

Table 1: Relevant critical aspects of the radio

E.	A varying electric field (acceleration of electrons) **induces** a perpendicular varying magnetic field
F.	A varying magnetic field **induces** a perpendicular varying electric field
G.	Magnetic poles of opposite polarity **attract**, same polarity **repel**

Table 2: Critical aspects of electromagnetism relevant to radio

From this analysis learning objectives or goals are specified. Activities are designed which are intended to invoke a pattern of variation which allows for the discernment of the aspects presented in tables 1 and 2. The design of the learning objectives of and activities in the lesson plan are described in the following section. They are also described in a separate document, a teaching manual, lecture slides and a student handout for the construction assignment all of which are written in the teaching language Swedish. Because their contents are described in the thesis they are not translated. These are appended to the thesis and can be found in appendices A, B, C.

Learning objectives

The lesson activity aims to develop the following capabilities in the participants:

- Describe the physical phenomena that allow for the radio as a technical system to function
- Describe the radios critical components individual functions and how they interact to fill its primary function
- Construct a simple model from a schematic with some instruction
- Describe some of the radios effects on societal development
- Identify system qualities in technical solutions
- Reason about technology's effect on human existence

Activities

According to the recommendations described previously the lesson is initiated with an introduction to the radio as an undivided whole. Figure 2 is presented to the student together with a brief outline of the history of the inception of the radio. The motivation for this is to give the subject a clear relevance structure in how the themes and concepts introduced can be generalised and used to understand other technical solutions and systems. This has to be explicit and clear to the learner in accordance with the recommendations of Felder & Brent (2007). Even further this understanding can give the students insight into how technology has affected and still affects the society in which they reside which can give further meaning to the object of learning.

After the initial phase of the lesson the activities which are meant to put critical aspect A from table 1 into focus is based on contrast. In order for the aspect to be discerned the electronic radio is contrasted with the 'tin can and string'-radio. These two objects as examples of communication solutions only differ in the medium in which the communication takes place. 'Means of communication' is introduced as a dimension of variation where 'electromagnetic induction' and 'vibrating medium' are introduced as separate values in that dimension. Tasking the class with stating the difference separates electromagnetism as a means of communication from the radio and puts that aspect in focus, which allows this aspect to be discerned by the students.

After this the aspect which has been separated is generalised. This is done by presenting different solutions which utilize electromagnetism as a means of communication and comparing them to the radio. By asking for the critical difference between the radio and the solution in question one further separates non-critical aspects of electromagnetism as a means of communication. This by putting into focus how the radio specifically utilizes the phenomenon, which is the topic of the following part of the lesson. It also allows the learner to connect the object of learning to familiar objects which exist in its margin which strengthens the relevance structure.

In order for the learners to correctly describe the function of the radio they need to be familiar with charge as a concept since the consequences of the movement of charged particles is central. This can be effectively illustrated using an analogy. By comparing the flow of charged particles in a conductor to the flow of water molecules in a conduit the critical aspects which characterize the former can be illuminated. The proposed way of doing this is presenting the following table to the students.

Aspect	**Electrical current**	**Water current**
Cause:	Is caused by an electrical field: a difference in charge between two points in space	Caused by a pressure difference in two points in liquid
Effect:	Causes a perpendicular magnetic field	Causes heat exchange within the liquid

Table 3: Structure of analogy demonstrating the behaviour of electrical current

In this phase of the lesson the students have been introduced to electromagnetism as a phenomenon only theoretically. Electromagnetism functions at a submicroscopic level which is not directly observable which produces a difficulty in practically demonstrating it (Michelini, 2007). In order for the students to get a better grasp of this phenomenon some sort of demonstration is often deemed appropriate. In this lesson the demonstration uses a pattern of variation which shows the result of changes in the dependent variables: the speed and proximity of the magnet and the size of the current.

A schematic for the circuit utilized is illustrated in Figure 3. By moving the bar magnet next to the coil and the students observing the resulting current on the multimeter, variation is implemented in the demonstration. This demonstrates the causal relation between changes in magnetic field strength and current in a conductor. Once this relation is established the reverse relation can be illustrated by using the circuit shown in Figure 4. By varying the current in a conductor and observing the changes in magnetic field strength by using a compass this relation is shown.

These relations are then used in explaining how a varying current in an antenna can induce a similar current in a receiver at some distance through the magnetic field it creates. What is important for this demonstration to show is that the amperemeter will not read any current unless the magnet is moving, which illustrates how a single stationary charge will not induce a magnetic field.

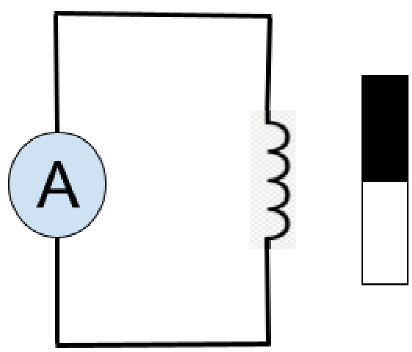


Figure 3: Diagram of circuit used to demonstrate relation between change in magnetic field strength and change in current.

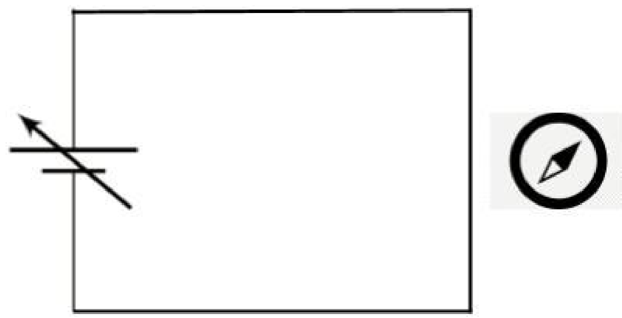


Figure 4: Diagram of circuit used to demonstrate relation between change in current and change in magnetic field strength.

The practical part of the lesson gives an opportunity for the students to construct their own physical model of the object of learning under some supervision and instruction. After completing the construction they are tasked with explaining how their model works when it detects a signal. This is deemed the culmination of the lesson, it is at this juncture where it will become clear if the students have grasped the concepts introduced enough to use them independently. Regardless, this task transfers the ‘responsibility of explanation’ onto the students which has been shown to lead to an awareness in the students of processes not before analysed (Michelini, 2007). This has also been shown to lead to the students' use of the formal concepts introduced in teaching, and even if done incorrectly is a desirable departure from the use of so-called common sense ideas. It is also in line with the ideas described in the introductory section where the cognitive models that the participants enter the activity with are put to test by being expressed in a social setting. The goal of this part of the lesson is to initiate classroom-wide discourse about the function of the radio where all the desired aspects can be put into focus.

The external horizon comes into play in the final part of the lesson which is the final fusion. Here the focus is shifted towards broadcasting as a sociotechnical system. By tasking students with explaining the social and historical effects of the radio's inception they will be forced to consider the societal context within which the radio operates. Consequently they will be given the chance to draw causal connections between the invention of the radio and other societal developments.

The lesson structure is summarised as follows:

- Introduction; presenting the main function of the radio and its history as a technical solution
- Introducing the three main components
- *Contrasting* out electromagnetism and the antenna as the means of communication
- *Generalising* electromagnetism and the antenna as a means of communication, by introducing alternate uses for it. This separates non-critical aspects, putting the critical aspect ‘receiving audio by means of encoded electromagnetic waves’ into focus.

- Elaborating on the mechanisms of electromagnetism through theoretical demonstration by analogy together with a practical demonstration
- *Fusion* by tying these mechanism to the function of the radio
- Guided construction of crystal radio model
- Further fusion by discussion on results from construction and how the model utilizes the phenomenon introduced in the lesson
- Discussion on the societal, historical implication of the radio's inception as an artefact and commodity.

Methodology

Data gathering
The study was conducted using semi structured interviews with participants after the lesson is simulated in front of them. They were informed of the purpose of the study, namely to get feedback for evaluation of each component of the design for further improvements. The lesson is simulated in front of prospective secondary school teachers acting as students. Two semi structured interviews (Esaiasson, 2012) within the themes considered of importance were conducted. The participants were two subjects, referred to as respondent A and respondent B. The subjects were found using the contact network within the master programme. The two subjects participated in the same session, but were interviewed separately. Since the lesson is structured in distinct steps, the interviews were structured such that the respondents were given a chance to share their experience of each substantial part of the lesson identified. This in order for them to share what practical concerns they might identify, which in turn can be used to improve the design. In order for the respondents to feel at ease giving their honest feedback, they were assured they would remain anonymous. The following approximate lines of questioning were used:

- From an average secondary school student's perspective, is the intended critical aspect discernable from the presented pattern of variation? Why/Why not?
- From an assumed student's perspective, is the lesson as a whole coherent and cohesive?
- Is the particular design choice optimal and feasible from a teaching perspective? If not, how can it be optimised or made feasible?

Data analysis
The research questions were posed around the theoretical framework of variation theory, which also affected the formulation of the interview questions. The respondents were briefed in the theoretical framework chosen, the recommended lesson structure given by Marton (2006), the patterns of variation and the rationale behind the choice of content and structure. They were asked to focus on the content, structure and presentation. In other words how the different patterns of variation were implemented practically. They were given an opportunity to share their views on the overall structure. The interviews were recorded for record keeping but not completely transcribed.

The data gathered from the interviews is based on the main components in the design and is outlined in the following section. The data is later used to determine which components of the design are most in need for improvements and in what aspect. It also gives grounds for speculation on the learning outcomes from an eventual real world implementation.

Results

The conclusions drawn from the contents of, along with some quotes from the interviews are presented in the following section. The conclusions are presented for each substantial part of the lesson design as outlined in the summary of the lesson activities.

Introduction: Initial fusion

Regarding the introduction to the lesson, respondent A had the following to say:

" *… lite kortfattat, man märkte att det gick lite för fort ...*"

This suggests that some concepts introduced should be elaborated further. From this view it is more beneficial for concepts such as commercialisation, commodity and others related to the radios sociocultural impact to be further explained within the introductory part of the lesson.'

Respondent B expressed the following:

"*Det var ganska lagom … om man är superintresserad får man lite att googla vidare på … det hade kunnat vara jättetorrt och tråkigt … det var intressant utan att bli för ytligt*"

viewpoint that the main concerns around the initial part of the lesson represented some compromise between higher level of detail and execution time. The introductory part of the lesson is in the respondents view most contingent upon the latter two factors. This can be seen as considerations made from the theoretical basis of cognitive load although this was not explicitly stated.

Initial contrast: separation of antenna

The contrast introduced in the following section was deemed by both respondents to be very clear, according to respondent B even too clear:

"*Man hade kunnat krångla till det lite mer ...*"

That is due to the students presumed lack of effort the activity would not be memorable. Nevertheless, the intended critical aspect is deemed likely to be discernible by most students.

Generalisation of electromagnetism as means of communication

When asked about the following separation of non-critical aspects the respondents had mixed responses. They were positive about the possibility to awaken relevant discussion about the possible differences between the different technical solutions presented, but at the same time concerned about the sheer amount of differences one could possibly think of between the ones in question:

"*Kanske att det skapar fler frågor … man tog det väldigt kort och det är ganska svårt.*"

For instance one could imagine quite many differences between a WiFi-router and a radio, and not many ways to know which one is critical.

Although this is a concern for all types of lesson formats which make use of peer discussion, the answers reflect upon a common dilemma addressed within the context of variation theory and lesson design in general. That is, if it is better for learning to make room for many aspects to be discerned at once. The respondents critique were in line with theory which states that example objects should be chosen such that the difference in primary function separates out as many non-critical aspects as possible. Which in turn suggests the design choice for this part of the lesson is not optimal.

Elaboration of EM

In regards to the elaboration of electromagnetism as a phenomenon, both respondents were positive to the use of analogy as a method to illustrate it’s mechanisms.

"*Intuitivt, bildas det ingen värme för mig … i min gymnasiehjärna*" - Respondent A

That is the fact that water transfers heat can not be considered a general intuitive concept suited for this setting. This points to the constructivist aspects of variation theory where the objects used for comparison have to be familiar for any conceptualisation of the unfamiliar object to be possible.

They also expressed the sense that although the lesson design presupposed some preexisting knowledge of concepts such as charge and frequency the design would benefit from elaborating more on how to conceptualise frequencies from different signals interacting during their transmission.

"*Lagt till någon fin animation med vågor*" - Respondent B
"*Man kanske kan visa det så… nu är vi på P3, nu är vi på P4 …*" - Respondent B
"*Spännande att den elektromagnetiska vågen matchade ljudvågen [i form] … "* - Respondent A

What they desired in other words was the invokement of a visual model for the waves and their interaction. Namely, the superposition quality of waves which is critical for understanding why modulation is even necessary.

Construction of crystal radio

Similar sentiments were expressed when asked about the construction phase of the lesson. Many of the components used in this part of the lesson were not introduced previously, and also not assumed to be critical for a cursory understanding of the crystal radio model’s function. The diode's role in rectifying the electromagnetic wave is one example of this. How the earpiece produces a pressure wave is also not introduced, but can be deduced from the fact that similar charges repel, a fact which is presented earlier in the lesson. This also echoes concerns with cognitive overload, that one might inadvertently have to feel obligated to allocate lesson time to explain the inner workings of a diode.

When asked if they thought that the average student possessing the necessary prerequisite knowledge would be able to explain the crystal radios function after active participation in the lesson, the respondents expressed concern about the magnitude of this task and how much further guidance the students would need besides the lecture they would receive initially. In light of this being the critical moment of the lesson, such considerations are expected to rise. This reflects the importance given to independent attempts by students to master the concepts presented, and is in line with the importance of laying 'explicative responsibility' upon the students expressed by Michelini et. al. (2007) and in extension the discursive tradition described by Schoultz (2001).

Conclusion and continuity
The respondents finally were also positive about introducing and utilizing the sociocultural perspective as a way to round out the lesson.

"*Man slipper det här jobbiga tekniska som man kanske inte är så bra på, och inte riktigt fattar och bara tänka lite flummigt … "* - Respondent B

In this view it would be a welcome change of pace from the technical and physical reasoning and could be seen as a 'lighthearted reprieve' from the more grueling responsibility of explanation endured previously. This sentiment is more in line with ideas of qualitative different 'modes of thinking' or what Sjöberg (2013) describes as different 'abilities' within technology. The more physical aspects of a technical solution are thought to require more effort to conceptualise than it's sociocultural aspects, which points to some sort of hierarchy where some abilities are deemed more valuable than others.

Discussion

The choices made in the lesson design and the conclusions drawn from the interviews are discussed in the following section.

Choice of theoretical frameworks
The choice of variation theory as a theoretical framework for the thesis is not an obvious one, nevertheless this theory has great applicability in instructive design particularly within science and technology. This is because the concept of relevance structure and 'ways of seeing' are central and often explicitly described within science education research. For instance one can consider the notion of systems and subsystems as a relevance structure, precisely because it is a way of 'seeing' the solution in question. It is in the view of the author that this congruence between the relevance structure presented and how one schooled in the subject of technology would view a solution is critical for students to adopt the desired reasoning.

One can also draw quite a natural parallel between 'ways of seeing' to the importance of visualisation, where descriptions of technical solutions and the natural forces with which they interact merely are means of forming a mental construct to predict behaviours. These mental constructs can be subjected to thought experiments which before physical, mathematical and computational modelling usually is the first step in predicting the behaviour of any system to an input. By presenting the radio in the manner the lesson plan intends, one gives the students a mental model from which its behaviour can be speculated on and subsequently developed. This has parallels to the work done by Euler et. al. (2020) on virtual learning environments (VLEs). In this study, the effects on participants from being more or less constrained and directed in the session. The similarity is the underlying assumption can be amplified from semi-independent exploration of which dimensions of variations govern the behaviour of the physical phenomena being regarded.

Along with this description of the 'way of seeing' the radio there are further ways of regarding the radio which are introduced. Quantifying the sociocultural significance of a technical artefact is after all the endeavour of the historian of technology rather than the technologist. Regardless, introducing and guiding the students in attempting this endeavor gives them the opportunity to fuse several perspectives of the radio giving the object greater relevance and meaning.

Metacognition, relevance structure and cognitive load

Elucidating these concepts for students also amounts to metacognitive instruction. This since it informs on both how to consider the formal 'schema' for a technical solution and the 'schema' for the sociocultural impacts of a technical solution. This also in a constructivist sense consequently gives learners guidance in the process of forming their own. This shows an overlap between variation theory and metacognitive considerations in lesson design which could be an avenue of further study and a source of further improvements on the lesson design.

The choice of including sociocultural aspects in the lesson design seems to go against the idea of avoiding cognitive overload by minimizing the amount of concepts introduced in a single lesson. This is a general problem in designing any lesson, but in particular within the framework of variation theory since it is contingent upon the introduction of auxiliary objects and concepts to make the important aspects of the object of learning discernable. One way of viewing this problem is one of optimization, the more auxiliary concepts one introduces, in theory the more reinforced the learning is. However this comes with larger 'costs' in cognitive load. This is not a trivial problem to solve, and there are no general rules of thumb for a situation like this, which is why teaching often is considered more of an art than a science. This is because it is difficult to measure when a student is reaching their threshold in cognitive load. The teacher needs to build a real intuition around his or her student's current abilities, never underestimating them and always presenting them with an appropriate level of challenge.

Choice of methodology

The methodology of the thesis was largely decided by the circumstances of the period the work of the thesis took place. In the best of circumstances, the thesis would have included more steps of the lesson study process outlined by Lo (2012). In particular a 'real life' test of the lesson design with the intended target group. Observations from such a study would bear more weight in validating the design choices made. The challenge with this approach is the significantly larger data set to analyse, while providing a greater opportunity to draw stronger conclusions would raise concerns of finishing the thesis in a timely manner. Observing the practical work of the students could also provide grounds for descriptions of the mechanisms behind learning from practical lesson activities.

Unfortunately due to the CoVid-19 pandemic all secondary schools held their lessons remotely, which makes testing practical lesson elements infeasible. A small number of potential respondents made any ambitions to provide insight into how potential secondary school teachers conceptualised the contents of the lesson impossible, instead the focus was changed and put on their experience of the simulated lesson and how they imagined it would be received by its intended target audience.

The validity of the input received can be questioned on the basis of the general approach of the thesis. Since the simulated lesson and consequent interview were structured according to the theoretical framework used, one can assume this somewhat limits the avenues of thought pursued by the respondents. Nevertheless, with the limitations in place the methods used in the thesis are deemed sufficient to answer the altered research questions and improve on the results. Under more favorable circumstances the thesis could have made larger contributions to the science education research field through attempts to study how prospective or practising secondary school students conceptualise electromagnetism.

One additional challenge conducting the interviews was separating the ‘how’ and the ‘what’ of each lesson element. That is to shift focus from the type of pattern of variation and its place in the sequence to its contents and how it was implemented. After all, the role of the respondents in the study was not to give their assessment on the validity of variation theory itself, but rather how the lesson design implements the theory to teach the desired content. In conclusion the thesis can be said to give some satisfactory answers to questions posed, that is that the overall design can be considered at least feasible in producing the desired outcome with several possible areas of improvement also identified.

Next design phase
Based on the conclusions presented in the previous section the lesson plan can be improved in the following ways:

- Further elaboration in the introduction about the themes, historical figures and forces behind the radio's inception.
- Simplify the generalization of electromagnetism as a means of communication
- Increased use of visualization in elaboration of electromagnetism
- Further emphasis on components introduced in construction phase

Based on this further research into this specific topic could be concerned with the following:

- Studying the effect of combining humanistic and technical aspects within instructional design.
- Attempts to describe the mechanisms in which visual representations aid in conceptualizing invisible physical phenomena.
- How learning from practical lesson elements can be understood from conventional theories of learning.

Conclusion

A reductive approach was used to determine the critical aspects of the radio. A lesson plan was designed according to the principles of variation theory. To further strengthen the relevance structure, the societal context of the radio's inception, and other related means of communication are also included in the lesson content. The lesson plan also includes a construction phase where a simple model of a radio is constructed, tested and it’s function discussed amongst the participants. The design followed the recommended sequence of patterns of variation to in theory allow the learner to discern all critical aspects. In order to collect data for improvements on the lesson design, the lesson was simulated in front of two prospective secondary school science and technology teachers. Their experiences of each component of the design were documented through interviews and used to identify and discuss how the design can potentially be improved.

References

Andersson, B. (2000): *Om ämnesdidaktikens natur, kultur och värdegrund*. Göteborgs universitet; IPD.
Bagno, E. Eyla, B. (1997). *From problem solving to a knowledge structure: An example from the domain of electromagnetism*. American Journal of Physics 65, 726
Dillon, J. (2009). *On scientific literacy and curriculum reform*. International Journal of Environmental & Science Education, 4
Euler, E. Gregorcic, B. and Linder, C. (2020) *Variation theory as a lens for interpreting and guiding physics students' use of digital learning environments*, Eur. J. Phys. **41** 045705

Esaiasson, P., Gilljam, M., Oscarsson, H. & Wängnerud, L. (red.) (2012). *Metodpraktikan: konsten att studera samhälle, individ och marknad.* (4., [rev.] uppl.) Stockholm: Norstedts juridik.
Felder, R. Brent, R. (2016): *Teaching and Learning STEM: A Practical Guide* Wiley
Fensham, P. (2003): *Defining an identity – The evolution of science education as a field of research*. Dordrechts, Kluwer Academic Publishers.
Gilbert, J. K. (2006). *On the nature of 'context' in chemical education*. International Journalof Science Education, 28
Guisasola, J. Almudi, J. M. Zubimendi, J. L. (2004). *Difficulties in learning the introductory magnetic field theory in the first years of university*. University of Basque Country
Holbrook, J. (2003). *Increasing relevance of science education: The way forward*.ScienceEducation International
Ian Abrahams & Robin Millar (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, DOI: 10.1080/09500690701749305
Jenkins, E. (2001): *Research in Science Education in Europe: Retrospect and Prospect*. I H. Behrendt, H. Dahncke, R. Duit, W. Gräber, M. Komorek, A. Kross & P. Reiska red.: Research in Science Education – Past, Present, and Future. Dordrecht: Kluwer Academic Publishers.
Marton, F. & Booth, S. (1997): *Learning and Awareness*. Mahwah, Lawrence Earlbaum Associates.
Marton, F. & Booth, S. (2000): *Om lärande*. Lund, Studentlitteratur
Marton, F., & Tsui, A.B.M. (2004). *Classroom discourse and the space of learning*. Mahwah, NJ: Lawrence Erlbaum Associates.
Michelini, Marisa & Mossenta, Alessandra & Testa, Italo & Viola, Rossana & Testa, Antonella & Guisasola, Jenaro. (2007). *Teaching Electromagnetism: Issues and changes.* University of Udine (s.70)
Mun Ling Lo. (2012). *Variation Theory and the Improvement of Teaching and Learning*. Göteborgs Universitet
Thong W. M. and Gunstone R. (2008) *Some Student Conceptions of Electromagnetic Induction*, Res. Sci.Educ. 38, 31-44
Petruzellis, Thomas. (2007). *22 Radio and Receiver Projects for the Evil Genius*. US: McGraw-Hill Professional.
Ritchie, S. M. & Tobin, K. (2001): *Actions and discourses for transformative understanding in middle school science class*. International Journal of Sci-ence Education 23, s. 283–299.
Ruse, M. (2005). *Entry for "reductionism"*: *The Oxford Companion to Philosophy* (2nd ed.). Oxford University Press
Schoultz, J. & Säljo, R. & Wyndhamn, J. (2001). *Conceptual knowledge in talk and text: What does it take to understand a science question?* Department of Thematic Studies, Linköping University; Department of Education, Göteborg University; Department of Teacher Training, Linköping University
Skolverket. (2011). Ämne – Teknik [*Ämnesplan*]. Accessed 2020-03-20: https://www.skolverket.se/download/18.4fc05a3f164131a7418107e/1535372300598/Technology-swedish-school.pdf

Sjöberg, S. & Hallström, I. & Klasander, C. (2013). *Ginners teknikdidaktiska handbok-Några teser om teknik, skola och samhälle*. Linköping: CETIS, Centrum för tekniken i skolan
Sweller, John (1988). *Cognitive Load During Problem Solving: Effects on Learning*. Cognitive Science. **12** (2)
Solomon, J. (1998): *About argument and discussion*. School Science Review80(291), s. 57–59.

Wulff, Alex. (2019). *Beginning Radio Communications: Radio Projects and Theory.* Apress, Berkeley, CA

Appendix A - Teachers manual

Syfte
Laborationen ska åskådliggöra hur elektromagnetiska fenomen kan observeras med hjälp utav en förenklad modell av en radio. Lärandemålen kan sammanfattas som följande, eleven ska efter utförd laboration kunna:

- Beskriva de fysiska fenomen som ligger bakom funktionen av radions komponenter med fysiska och tekniska modeller och begrepp.
- Beskriva radions viktigaste beståndsdelar utifrån deras individuella funktioner och hur de samverkar för att fylla dess yttersta funktion.
- Konstruera en enklare modell från ritningar och kopplingsschema.
- Beskriva radions historiska påverkan på samhällets utveckling
- Identifiera systemegenskaper generellt hos tekniska lösningar
- Resonera kring teknikens påverkan på den mänskliga tillvaron

Önskade förkunskaper
Eleverna bör ha en översiktlig förståelse av följande begrepp:

- Protoner och Elektroner (Elektrisk laddning)
- Ström, spänning, induktans
- Magnetism, permanentmagneter och magnetfält
- Frekvens, våglängd, ljud

Beräknad tidsåtgång
60 - 90 minuter

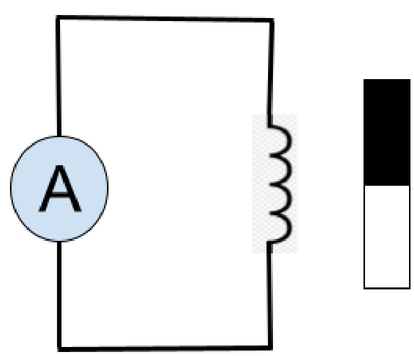
Nödvändiga material och verktyg
Rör (papper, plast, PET-flaska)
Koppartråd
Piezoelement
Diod
Sax
Avbitartång
Tejp

Häftmassa
Spole
Multimeter
Permanentmagnet
Kompass

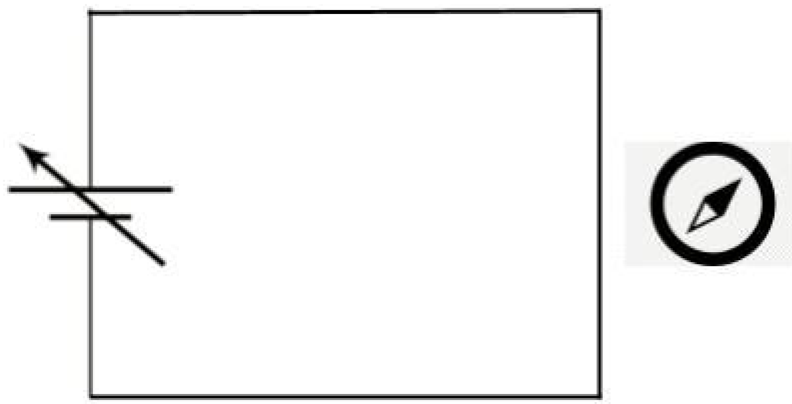
Utförande
Laborationen inleds med presentationen av en trådradio, alltså en konstruktion bestående av två pappersmuggar med en tråd emellan två hål i botten på muggarna, och en elektronisk radio. Konstruktionen förklaras och klassen ombeds att förklara hur radion fungerar. Efter att trådradions funktion förklarats övergripligt ställs frågan till klassen vad som är skillnaden mellan trådradion och den elektroniska radion.

Det som bör behandlas i diskussionen är den kritiska skillnaden mellan trådradion och elradion, nämligen vilket eller vilka fysiska fenomen eller medium som utnyttjas för att överföra information. I trådradion är det tråden eller snöret som överför en vibration som uppstår i pappersmuggen när den talas i. I elradion är det ett elektromagnetiskt fält som agerar som snöre konceptuellt sett. Däremot skiljer det elektromagnetiska fältet i att det sätts i gungning genom andra mekanismer.

För att generalisera konceptet kommunikation med hjälp av elektromagnetism presenteras ytterligare tekniska lösningar som utnyttjar detta. Mobiltelefoner, satelliter, WiFi-router är olika exempel som bör tas upp som visar hur elektromagnetismens mekanismer utnyttjas på olika sätt. Att introducera dessa exempel ska få eleverna att inse att radions kritiska aspekt kan defineras mer specifikt, att den förmedlar information genom att omvandla en elektromagnetisk våg till en ljudvåg.



Därefter bör dessa mekanismer illustreras. Ett enkelt sätt att illustrera detta är att utgå ifrån laddningar och magnetisk attraktion. En ström i en ledare är ett uttryck för ett elektriskt fält, där negativa laddningar rör sig genom ledaren mellan två punkter med potentialskillnad. Ett förändrat magnetfält leder till ett förändrat elektriskt fält som leder till en förändring i strömmen. Detta kausala sambandet illustreras bäst genom att koppla en spole till en amperemeter och visa hur strömmen varierar när en permanentmagnet rör sig nära spolen.



Sambandet bör även illustreras omvänt vilket ger principen bakom radion. Nämligen att en förändring i strömmen orsakat av en förändring i det elektriska fältet ger upphov till en förändring i det magnetiska fältet. Detta illustreras genom att variera strömmen i en ledare med hjälp av ett spänningsaggregat och observera hur en kompassnål ändrar riktning bredvid ledaren. På detta vis påverkas ledare av varandra och fenomenet kan utnyttjas för kommunikation.

Eleverna presenteras därefter med ritningar och instruktioner för att bygga en enkel modell av en radio. Modellen är egentligen en enkel resonanskrets. Det som eleverna bygger är en spole. För att kunna ställa in kretsens resonansfrekvens och ta emot sändningen från en radiostation tillåter konstruktionen att dess induktans varierar med hjälp av en relativt enkla mekanism.

Eleverna får efter att ha färdigställt konstruktionen variera och induktansen och dokumentera vad som händer i mallen som finnes i laborationshäftet. Elevernas resultat tas därefter upp i helklass och diskuteras tills det rätta sambandet kan beskrivas av eleverna.

Lektionen avslutas med att man belyser och befäster sambandet mellan kretsens resonansfrekvens, som beror på vilken induktans som ställts in, och vilken radiostations sändningsvågor som tas upp av kretsen.

I denna avslutande diskussion bör även radions samhällshistoriska roll diskuteras. Utgående från öppna frågor får eleverna öva på att beskriva hur en teknisk lösning får en samhällelig påverkan och driver en historisk utveckling.

Lektionsstrukturen kan sammanfattas som följande:

1. Inledning som introducerar radion som helhet
2. Seperation av elradions kritiska aspekt (Kommunikationsmediet är elektromagnetism)
3. Demonstration av hur elektromagnetism yttrar sig (Generalisering av elektromagnetismens aspekter)
4. Konstruktion av spole inklusive test (eget arbete)
5. Diskussion av resultat
6. Sammanfattning av radions funktion
7. Diskussion av historisk påverkan

Teoretiskt ramverk

Lektionsupplägget ihop med målsättningen är informerade av variationsteori. Målsättningen är utformad så att den innehåller både kortsiktiga mer mätbara mål och långsiktiga mål om vilka mer generella förmågor som aktiviteten söker att utveckla. Enligt Marton och Tsui (2004) utvecklas generella förmågor från att behandla olika specifika fall.

Enligt variationsteori är en nödvändig förutsättning för lärandet av ett lärandeobjekt att elever skall ges möjlighet och urskilja kritiska aspekter, det som skiljer objektet gentemot besläktade objekt.

Enligt detta ramverk rekommenderas en viss lektionsstruktur där först en helhet presenteras (fusion), därefter presenteras lärandeobjektet ihop med ett objekt som helst endast skiljer i den kritiska aspekten (kontrast). Sedan rekommenderas generalisering av den kritiska aspekten. Till sist bör helheten refereras tillbaka till tillsammans med den kritiska aspektens roll i detta. (Lo, 2012). Strukturen efterliknar 5E fast är mer specifik i hur lärandeobjektet ska behandlas i varje del.

Inledningen till lektionen utformas så att en så kallad relevansstruktur byggs upp för eleverna. Radions olika delar, deras funktioner och hur de interagerar presenteras inte enskilt utan tillsammans med de andra delarna i kommunikationssystemet den ingår i, samt andra kommunikationsmedel. I denna presentation sätts radion i kontrast gentemot mer primitiva lösningar, där trådradion specifikt används som ett enkelt exempel för att peka på den väsentliga skillnaden.

När den kritiska aspekten (utnyttjandet av elektromagnetism) är åskådliggjord generaliseras den aspekten genom att olika lösningar som har denna aspekt presenteras. Efter detta demonstreras hur mekanismerna fungerar. Anledningen att attraktion används som utgångspunkt i att förklara elektromagnetismens mekanismer är att det är ett koncept som är generellt för fysiken och som elever ofta har en intuition för. Det är även ett sätt att introducera variation i demonstrationen, där det blir tydligt att rörelse och förändring av magnetfält är det kritiska. Detta skapar även en medvetenhet av magnetfälten kring elektriska strömmar. (Michelini, 2007)

När denna medvetenheten är skapat går det att befästa den genom att skapa ytterligare kopplingar till koncept som eleverna redan är mer familjära med. Anledningen till att ett magnetfält skapas när en ström uppstår behöver även förstås och illustreras med analogi till vattenflöde. Principen att energin alltid bevaras gör att när en elektron ändrar riktning i spolen så omvandlas förändringen i rörelsemängd till ett magnetfält. Samma princip gör att ett vattenflödet i ett rör kommer generera värmeenergi när vattenmolekylerna kolliderar med molekylerna på rörets inneryta.

Eleverna får efter att ha färdigställt sin konstruktion sedan möjligheten att med hjälp av begreppen som introducerats beskriva hur deras konstruktion fungerar. Detta är viktig för att eleverna ska utvecklas i sin förståelse, att gå ifrån att använda allmänna begrepp och använda fysikens terminologi i sina förklaringar. (Michelini, 2007)

Syftet med att avsluta lektionen med en diskussion av radions samhällshistoriska påverkan är att det lyfter lektionens fokus tillbaka till helheten när radion kopplas till sitt tematiska fält. Det är ett sätt att ge mening till radion som lärandeobjekt, mening som gör att lektionen och kunskaperna som söks förmedlas känns relevant för eleverna. (Lo, 2012)

Källor

Marton, F., & Tsui, A.B.M. (2004). *Classroom discourse and the space of learning*. Mahwah, NJ: Lawrence Erlbaum Associates.
Michelini, Marisa & Mossenta, Alessandra & Testa, Italo & Viola, Rossana & Testa, Antonella & Guisasola, Jenaro. (2007). *Teaching Electromagnetism: Issues and changes.* University of Udine (s.70)
Mun Ling Lo. (2012). *Variation Theory and the Improvement of Teaching and Learning*. Göteborgs Universitet

Appendix B - Student handout

Introduktion
Du har i början av lektionspasset fått introducerat till dig radions uppbyggnad, funktion och historia. Din uppgift nu är att konstruera en enkel modell av en radio, försöka ta emot en radiosignal och sedan förklara hur detta sker.

Material och verktyg

Till ditt förfogande har du följande:

- 1 st Rör (plast/papp/PET)
- 2 m Koppartråd
- 1 st Diod
- 1 st Piezoelement
- Sax
- Tejp
- Avbitartång

Syfte

Du ska efter utförd laboration kunna:

- Beskriva de fysiska fenomen som ligger bakom funktionen av radions komponenter med fysiska och tekniska modeller och begrepp.
- Beskriva radions viktigaste beståndsdelar utifrån deras individuella funktioner och hur de samverkar för att fylla dess yttersta funktion.
- Konstruera en enklare modell från ritningar och kopplingsschema.
- Beskriva radions historiska påverkan på samhällets utveckling
- Identifiera systemegenskaper generellt hos tekniska lösningar
- Resonera kring teknikens påverkan på den mänskliga tillvaron

Utförande

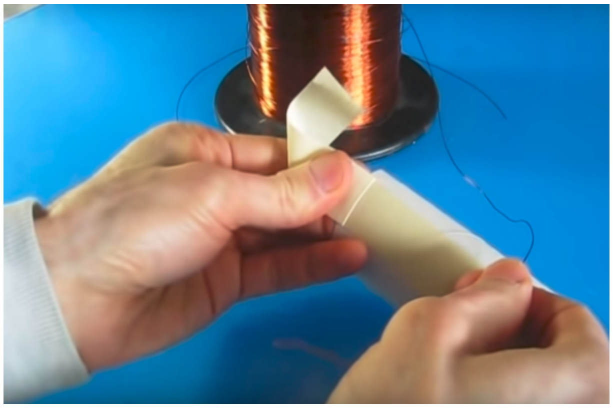
Det du skall bygga först är två **spolar** av koppartråd. Detta gör du genom att vira koppartråd runt röret som du har fått. Börja med att vira antennspolen, denna ska viras 25 varv runt röret. Ifall du använder ett papprör, se till att börja med att fästa en tejpremsa längs röret.

1. Fäst en tejpremsa i rörets längd på rörets kortsida enligt Figur 1. Använd denna remsa för att fästa koppartråden på sin plats mot kortsidan av rörets utsida enligt Figur 2 och Figur 3. Fäst tråden ett par decimeter från sin ände så att änden är fri och kan kopplas emot.
2. Vira färdigt antennspolen (25 varv).
3. Lyft upp tejpremsan mot spolen och fäst spolens andra ände mot röret enligt Figur 4. Lämna även i den här änden ett par decimeter av tråden fri där du klipper.

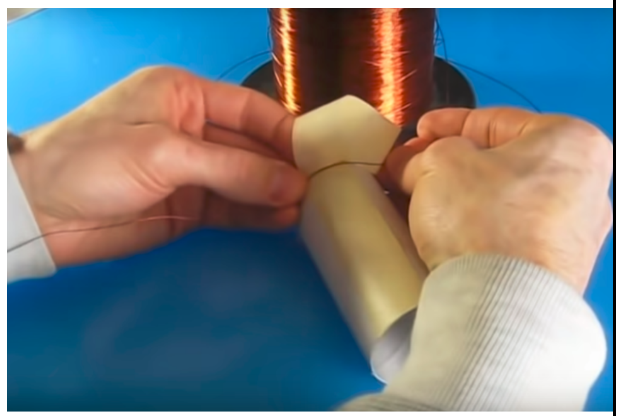
Du ska nu vira inställningsspolen. Denna ska viras precis bredvid antennspolen på samma sätt men skall istället viras 90 varv.

1. Lyft upp tejpen till ett par millimeter efter där antennspolens ände fästes. Fäst här inställningsspolens första ände på samma sätt som antennspolen. Se Figur 5.
2. Vira spolen 90 varv runt röret.

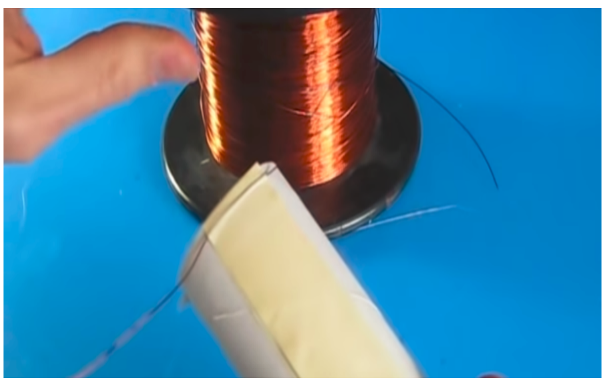
3. Lyft upp tejpen och fäst fast inställningsspolen andra ände, klipp även här så att tråden har ett par decimeter ände kvar att koppla mot.



Figur 1: Hur röret förbereds för att tvinna spolen.

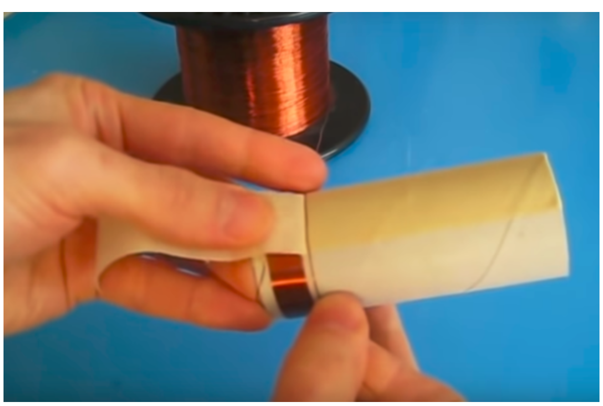


Figur 2: Hur koppartråden fästs mot röret. (1)

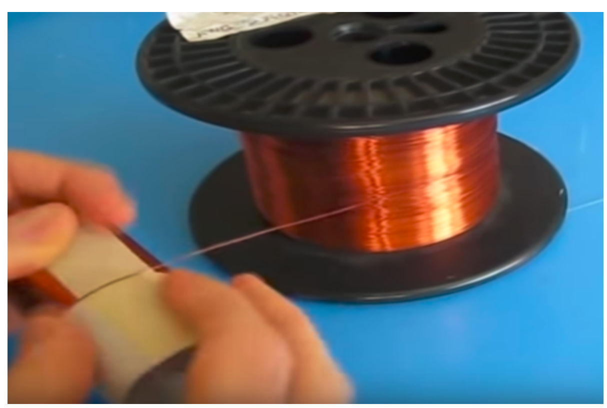


Figur 3: Hur koppartråden fästs mot röret. (2)

Figur 4: Fäste av antennspolens andra ände mot röret.



Figur 5: Fäste av inställningsspolens första ände.

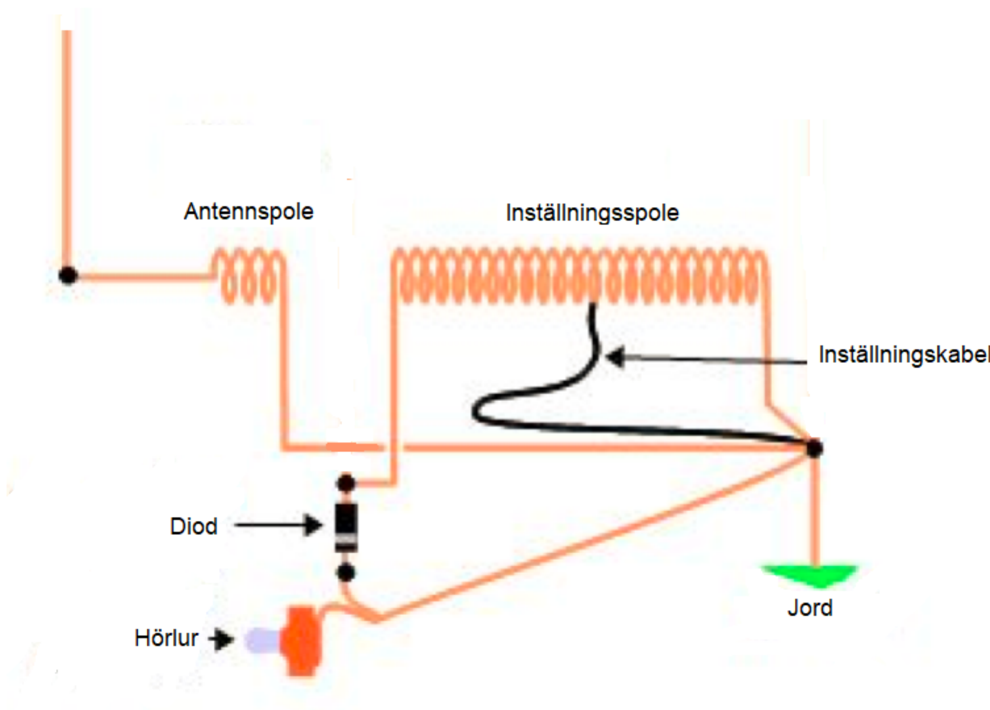


Figur 6: Fäste av inställningsspolens andra ände.

Utförande forts.
När spolarna är färdiga skall radion kopplas ihop. Följ kopplingsschemat i Figur 7. Som jord kan du använda ett bordsben eller ett element. För att inställningskabeln ska kunna få kontakt med inställningsspolen behöver emaljen på lindningarna slipas av. Slipa försiktigt så att emaljen **mellan** lindningarna inte skadas. Även emaljen på änden av inställningskabeln behöver slipas bort så att denna kan göra kontakt på spolen. För att göra kontakt kan du helt enkelt vira ihop ändarna på kablarna mot komponenterna. Kom ihåg att ändarna behöver också få emaljen bortslipad för att få kontakt med komponenterna.

När du har kopplat ihop radion kan du börja ställa in den. Lyssna i hörluren medan du för inställningskabeln längs kontaktytan du skapat på inställningsspolen. När du har plockat upp en signal kan du fästa kabeln på spolen med hjälp av häftmassa. Radion bör kunna plocka upp en svag signal, får ni inte ut något ljud så kontrollera kopplingarna. Se till att alla kopplingar till jord är ordentliga.

Försök nu tillsammans med tiden ni har kvar förklara vad som händer med hjälp av koncepten och begreppen ni fått introducerat i början av passet.



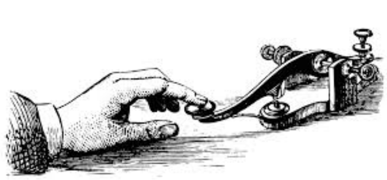
Figur 7: Kopplingschema för kristallradio.

Appendix C - Lecture slides

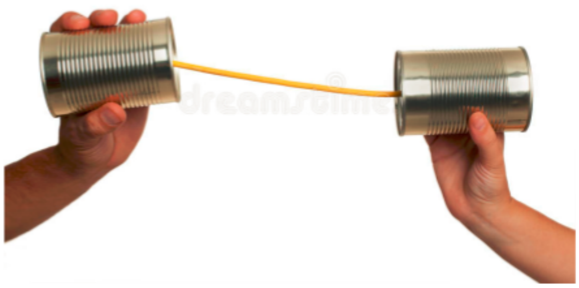
Radiolaboration

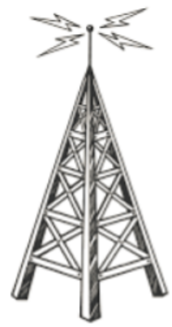
Hur kom radion till?

- I mitten av 1800-talet upptäcktes radiovågor, alltså att det nu gick att skicka telegrafsignaler trådlöst istället för över kablar dragna långa sträckor.
- Mot slutet av 1800-talet byggdes den första helt trådlösa telegrafen av italienaren Marconi.
- Hans företag Marconi Radio Company blev världsledande inom radioutrustning och sägs ligga bakom radions *kommersialisering.*



Vad är en radio?





Vad är en radio?

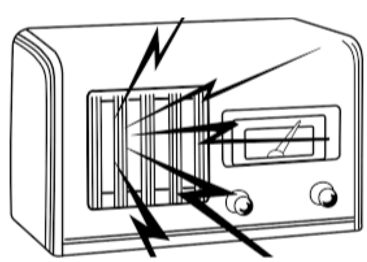
- Det som skiljer en “trådradio” från en “elradio” är vilket **kommunikationsmedium** som utnyttjas.
- Trådradion använder **vibrationskänsligt material** för att transportera ljudvågor längre sträckor.
- Elradion använder **elektromagnetiska vågor** för att förmedla information i form av ljudvågor.
- Även om radion var den första tekniska lösningen som utnyttjade elektromagnetism för trådlös kommunikation, var det inte den sista.

Vad är en radio?

- Vad skiljer dessa tekniska lösningar från en radio?

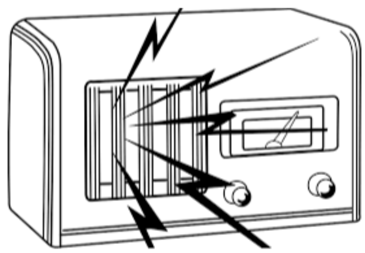
Vad är en radio?

- En radio definieras alltså inte endast utifrån vilket **medium** den utnyttjar, utan också **vad** som förmedlas och mer specifikt **hur**.
- En radio **tar emot** och **spelar upp** ljud.
- Det är alltså **ljud** som förmedlas långa sträckor med hjälp av **elektromagnetiska vågor** och kommunikationen går endast åt ett håll.



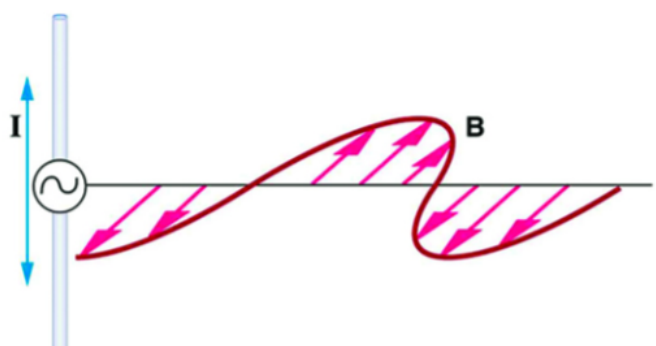
Vad är en radio?

- En radio definieras alltså inte endast utifrån vilket **medium** den utnyttjar, utan också **vad** som förmedlas och mer specifikt **hur**.
- En radio **tar emot** och **spelar upp** ljud.
- Det är alltså **ljud** som förmedlas långa sträckor med hjälp av **elektromagnetiska vågor** och kommunikationen går endast åt ett håll.



Hur fungerar radion?

- Elektromagnetism upptäcktes av skotske fysikern Maxwell på 1800-talet.
- Ändring av strömmen i ledare → Skapar magnetfält kring ledare
- Ändring av magnetfältet kring ledare → Skapar ström i ledare
- Med andra ord kan man med rätt ström och rätt ledare skapa en våg i magnetfältet som färdas med ljusets hastighet.



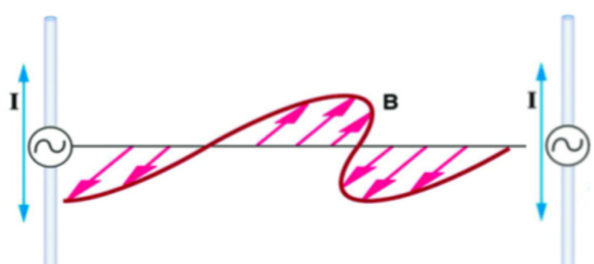
Elektricitet och rinnande vatten

- Anledningen till att ett magnetfält skapas har med energibevarelse att göra.
- När elektronerna 'tappar' rörelsemängd i spolen övergår en del av den energin till ett magnetfält
- På liknande sätt övergår rörelseenergin i rinnande vatten också över till en annan form
- Elektricitet kan jämföras med rinnande vatten.

Elektricitet	**Rinnande vatten**
Flöde av elektroner i ledare	Flöde av vattenmolekyler
Överbliven rörelseenergi övergår till magnetfält	Överbliven rörelseenergi blir till värme

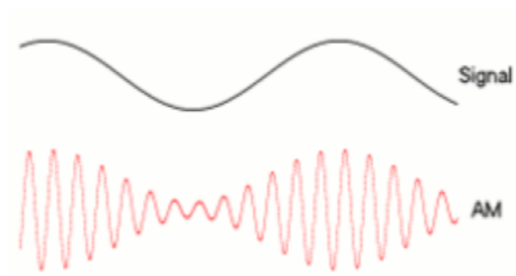
Hur fungerar radion?

- Denna våg kan färdas långa sträckor väldigt fort.
- När den möter en annan ledare kan den få en liknande ström att uppstå i den andra ledaren.
- Detta kallas **induktion** och är hur antenner överför information till varandra. Informationen i radions fall är en ljudvåg som strömmen ska efterlikna.
- Att man försöker göra att den elektromagnetiska vågen efterliknar ljudvågen brukar kallas att ljudet **kodas** för att sedan **avkodas** av mottagaren.



Hur fungerar det med flera radiostationer samtidigt?

- För att kunna lyssna på en station bland flera som sänder samtidigt behöver radion ett sätt att 'välja' vilken station den ska lyssna på.
- Stationerna behöver också 'samsas' om sändingsutrymmet.
- Det enklaste sättet att göra detta är **amplitudmodulering.**
- Radion ställs in så att den tar emot vågor av en viss frekvens.
- Ljudet som ska skickas **omkodas** så att topparna och dalarna matchar.



Bygge

- Nu är det dags för bygget.
- Se till att du har fått följande: 2m Koppartråd, Pappersrör, Tejp, Hörlur, Diod, Sax, Avbitare, Sandpapper

1. Börja med att vira spolarna, följ elevhandledningens instruktioner för detta.
2. Koppla upp kretsen enligt handledningen.
3. Ställ in kretsen och försök på en signal.
4. Diskutera i gruppen **vad** det är som händer och **varför** det händer.
5. Diskussion i helklass.

Radions påverkan

- Hur skulle du beskriva radions historiska och samhälleliga påverkan?
- Diskutera med bordskamrater (5 min)
- Diskussion i helklass