Welcome to NorDiNa 6(1)!

As editors we are happy to present to you the first 2010 issue of NorDiNa. Our journal is running well in terms of incoming manuscripts, which means that Nordic researchers in science education are productive, and that they see NorDiNa as a good place for publishing. We appreciate both!

Unfortunately, this development also means an increased work load for editors and our reviewers. In turn this has led to a longer response time in all phases of the process of publishing in NorDiNa. Still we take the chance of welcoming even more manuscripts, as well as smaller informative contributions under our headings “Curriculum developments and projects” and “Recent dissertations” (which we have none of in this issue).

As usual, the articles in this issue span over a wide field:
Marianne Ødegaard and Nina E. Arnesen report from the extensive PISA+ video study in Norwegian schools. The study of what happens in the science classroom reveals that science teachers are quite open to student initiatives, and that the dominating learning activity is going through new subject matter in dialogue with the students. However, the study showed very little inquiry where students used practical experiments as a basis to actively talk science. This provides for interesting comparisons with the results in two articles from Swedish research groups concerning inquiry and practical work in science teaching. Jakob Gyllenpalm, Per Olof Wickman and Sven-Olof Holmgren investigate inquiry-oriented approaches to science teaching. They demonstrate a wide variety of how teachers perceive and realise inquiry-based teaching, and discuss problems associated with inquiry and the possible consequences of these for teacher education, in-service training and curriculum development. Per Högström, Christina Ottander and Sylvia Benckert show in their article related results, that teachers have a variety of aims with practical work in science, conceptualised as helping students develop their understanding, to make them interested and to develop their laboratory skills.

A study on technology education in elementary school is presented by Eva Björkholm. She investigates boys’ and girls’ interests and attitudes, and finds interesting differences but also similarities. While gender differences were found in views of possible future occupations, pupils’ views of future occupations in technology showed no significant gender differences.

The article by Hanne Moeller Andersen and Lars Brian Krogh also relates to teachers. They investigate science and mathematics teachers’ core teaching conceptions (CTCs) and their implications for engaging in cross-curricular innovations. Based on their results, they argue that teachers’ CTCs come in subject specific flavours, encompassing their purpose for teaching the subject, their conceptions of teaching and learning, and their conceptions of interdisciplinary teaching, and that assessing and addressing typical and personal CTCs is crucial to a successful implementation of current reform-initiatives.

Students' language use in biology is investigated by Clas Olander and Åke Ingerman, by analysing the discussions of 15-year old Swedish students participating in teaching activities concerning biological evolution. When interpreting the discussions and strategies students used for contextualising scientific terms in light of Vygotsky's theories, they found that students formed rather sound and coherent scientific explanations when combining the terms into thematic patterns.

Silje Rødseth and Berit Bungum ask "What has inspired the physics student?", and report from a qualitative study based on questionnaires and interviews with physics students at university level. Their results indicate that teachers are important for inspiration, but also that many students rather see their interest in physics as a genuine, inborn characteristic of their personality.

As always: Enjoy your read!

Berit Bungum   Anita Wallin   Björn Andersson

Silje Rødseth har en mastergrad i fysikk fra teknologistudiet ved NTNU. Hennes masteroppgave var fagdidaktisk rettet og tok for seg hva som kjennertegner begynnerstudenten i fysikk. Artikkelen presenterer noen resultater fra denne studien.

Berit Bungum har en cand.scient. grad i fysikk og doktorgrad i fagdidaktikk. Hun er førsteamanuensis ved Institutt for Fysikk, NTNU, og har fungert som veileder for Silje Rødseth.

SILJE RØDSETH OG BERIT BUNGUM
Norges Teknisk-Naturvitenskapelige Universitet
siljeruud@gmail.com
berit.bungum@ntnu.no

Hva inspirerer til fysikkstudier? En undersøkelse av begynnerstudenter på fysikk

Abstract
Low recruitment to studies in science and technology is a matter of great concern, and many initiatives are made in order to motivate young people to pursue a career in subjects such as physics. This article presents a study of how a sample of Norwegian first year university students of physics look upon their choice of study and what they see as main sources of inspiration in this regard. The study is undertaken by means of a survey and interviews with students. Results indicate that teachers are important for inspiration, but also that many students rather see their interest in physics as a genuine, inborn characteristic of their personality. Interviews revealed that parents and family also have been highly important for the students' development of interest in physics.

Innledning
Svikt i rekruttering og unge menneskers manglende interesse for naturvitenskap og teknologi er gjenstand for stor bekymring (se f.eks. Osborne, Simon & Collins, 2003). Følgelig brukes det store ressurser på tiltak for å fremme rekruttering til studier innen disse fagområdene. Det legges vekt på å bevisstgjøre ungdom at vitenskap er nyttig og positivt for samfunnet, og de mange yrkesmulighetene studier på dette feltet gir. Undersøkelser om yrkesvalg tyder imidlertid på at ungdom velger studier mer av interesse enn av nyttehensyn, og at faglige interesser er ledd i de unges identitetsbygging og således inngår i et selvrealiseringsprosjekt (Schreiner & Sjøberg, 2005). Det hevdes videre at det å fordype seg i naturvitenskap ikke er i overensstemmelse med hvordan ungdom i en senmoderne tid ønsker å bygge sin identitet, og at dette kan være årsak til sviktende rekruttering i vestlige land.

Mange studier har undersøkt holdninger til fysikk spesielt og naturvitenskap generelt blant skoleelever (f. eks. Angell, Guttersrud, Henriksen & Isnes, 2004; Hansson & Lindahl, 2007; Häussler, Hoffman, Langeheine, Rost & Sievers, 1998; Krogh & Thomsen, 2005; Osborne, Simon & Collins, 2003; Reid & Skryabina, 2002). Noen av disse peker på årsaker til at elever synes å ta avstand fra og miste interessen for faget i løpet av sitt utdanningsløp. Denne artikkelen utfyller dette bildet ved å fokusere på ungdom som faktisk har valgt å studere fysikk på universitetsnivå. Gjennom en empirisk undersøkelse av et utvalg av norske begynnerstudenter i fysikk ønsker vi å kaste lys over hva som kjennetegner deres faglige interesse og hvordan denne utgjør en del av deres selvoppfatning. Vi ser på hvordan og når interessen har oppstått, hva som har inspirert studentene til å velge et studium i fysikk og hvilken rolle skolens undervisning og lærere har hatt i å vekke eller videreutvikle studentenes interesse for fysikkfaget.

Interessebegrepet

Interessebegrepet brukt i dagligtale innebærer at man er opptatt av eller har et engasjement for noe. Man er tilbøyelig til å bruke tid på det man er interessert i og ønsker å vite mer om det. I hvor stor grad interesse for noe innebærer et slikt engasjement, avhenger imidlertid av hva man mener med interesse. Innenfor forskning på interesse har begrepet blitt knyttet til blant annet nysgjerrighet og lærelyst (Hidi, Krapp & Renninger, 2004). Det kan også forstås som en vekselvirkning mellom et individ og dets omgivelser (Troelsen, 2006). Det å vise interesse for noe sees da som et ledd i det å samhandle med verden. En slik definisjon er nokså vid og utfordrende å arbeide ut fra i forskningssammenheng, og derfor har begrepet blitt nyansert gjennom mer spesifikke termer som hver for seg blir mer presise og entydige.

En måte å nyansere interessebegrepet på, er å se på hvordan interessen har oppstått. Interessen kan stamme fra noe i personens omgivelser, for eksempel fra undervisning eller media. Den kan være forbigående eller av mer varig art, men kjennetegnes ved at den har begynt på et bestemt tidspunkt eller i en bestemt situasjon. Denne typen interesse betegnes som *situasjonell*; den har sin opprinnelse i situasjonen en person befinner seg i, og det analytiske fokus ligger på å beskrive og forklare hva i omgivelsene som har utløst interessen (Hidi et al., 2004; Dohn, 2007). For eksempel kan elevers læringsmiljø og undervisningssituasjon spille en viktig rolle i det å stimulere en situasjonell interesse.

I motsetning til den situasjonelle interessen, kan interessen også være oppstått med utgangspunkt i genuint personlige egenskaper. Den er da å regne som et karaktertrekk ved personen selv og gir seg utslag i at personen er interessert i en bestemt type temaer eller aktiviteter over tid (Hidi et al., 2004). I slike tilfeller kalles interessen for *individuell*; den er individuelt forankret hos hver enkelt.

En situasjonell interesse kan være utgangspunkt for en mer varig og dypere individuell interesse. Blant annet ser Krapp (2002) interesse som situasjonell og oppstått som følge av en motiverende erfaring eller annen stimulans utenfra. Dersom den vedvarer og får utvikle seg, kan den til slutt manifestere seg som er mer individuell interesse; en varig opptatthet av å utforske interesseområdet videre.

Enkelte forskere har mer fokus på den individuelle interessen, som er en mer vedvarende tilstand, og hvilke valg en person gjør på basis av den (f.eks. Hidi et al., 2004). For eksempel kan en interesse for realfag lede til at man velger et studium innenfor fagfeltet, men den samme interessen kan også få en til å abonnere på et realfaglig tidsskrift uten at man velger den type utdanning. Én og samme interesse kan altså lede til svært forskjellige konsekvenser for den enkelte. Troelsen (2006) har i sin undersøkelse vist hvordan mennesker som på hver sin måte har et arbeid relatert til naturvitenskap har utviklet sin interesse på ulike måter gjennom barndommen, skoletiden og inn i yrkeslivet. Hennes undersøkelse viser at informantene ikke bare gjort ulike utdanningsvalg, men de har også interessert seg for naturvitenskap på forskjellige måter. Troelsen sier det slik; *"Interessens art er avhengig av interessens uttrykk"* (Troelsen, 2006, s. 12). Man må se på hvordan en interesse fører til handling, altså hvilke praktiske konsekvenser interessen får for den enkeltes valg i livet.

Interesse for fysikk: Tidligere forskning

Flere studier har undersøkt skoleelevers interesse og motivasjon for fysikk og naturvitenskap mer generelt. De viser at mens elever i yngre årsklasser ofte viser stor entusiasme for naturvitenskapelige temaer, synker ofte motivasjonen når elevene når ungdomsalder (f.eks. Lindahl, 2003). Videre synes det som om tendensen med at naturfagsinteressen avtar med årene slår hardest ut for fysikk (se Osborne, Simon & Collins, 2003). Undersøkelser tyder også på at valg av fysikk og kjemi ofte er instrumentelle valg, ved at det gir tilgang til attraktive utdannelser og karrierer (se Lyons, 2005). Valg av biologi derimot synes å oftere være motivert ut fra interesse og indre motivasjon. Den norske FUN-undersøkelsen (FysikkUtdanning i Norge) viser imidlertid at elevene som har valgt fysikk som fag i videregående skole er svært fornøyd med faget, til tross for at det framstår som arbeidskrevende og vanskelig (Angell et al., 2004). De oppgir de filosofiske sidene av faget som vel så viktig for deres interesse enn nytteperspektiver og hverdagstilknytning i faget. Denne orienteringen gjenfinnes også blant studenter som har valgt fysikk som studievei (Rødseth & Bungum, 2007).

Elever hevder også at de i hovedsak har valgt faget på grunn av en genuint faglig interesse, og at familien i liten grad har hatt betydning for deres valg (Angell, Henriksen & Isnes, 2003).
Krogh og Thomsen (2005) viser imidlertid at kulturelle forhold i familien likevel har vesentlig betydning for elevers interesse for fysikkfaget. Lyons (2005) viser til at en slik påvirkning, som kan påvises som korrelasjoner mellom familiebakgrunn og studenters faktiske valg, ikke i samme grad framkommer i studenters egne begrunnelser for utdanningsvalg. De er følgelige ikke nødvendigvis bevisst på, eller gir eksplisitt uttrykk for, hva som har påvirket egne valg.

Forskningsfokus og metoder i undersøkelsen

Undersøkelsen som presenteres i denne artikkelen søker å belyse hva som kjennetegner interessen for fysikk blant universitetsstudenter som har valgt dette faget som sin studievei. Forskningsspørsmålene er:

- Hvordan og når har interessen for fysikk oppstått?
- Hvilken betydning har undervisning hatt?
- Hva har inspirert studentene til å velge et fysikkstudium?

Det vil kunne være store individuelle forskjeller i hva slags interesse fysikkstudentene har og hvordan den har oppstått. For å få et bilde av denne bredden, kombinert med en dypere forståelse av interessen enkeltstudenter har utviklet for faget, har vi kombinert en kvantitativ studie med dybdeintervjuer av utvalgte respondenter.

Utgangspunktet er en større undersøkelse, kalt ”Hvem er fysikkstudenten?” (se Rødseth & Bungum, 2007), hvor et årskull av 1. års fysikkstudenter ved Norges Teknisk-Naturvitenskapelige Universitet har besvart et spørreskjema med spørsmål om sine interesser innen fysikk, hva de anser som viktige motivasjonsfaktorer for sitt studievalg, samt sine yrkesmessige framtidsplaner. Årskullet som ble undersøkt besto av 150 studenter, og 133 av disse besvarte spørreskjemaet, som ble delt ut på en forelesning. I denne artikkelen rapporteres studentenes svar på et åpent spørsmål i dette spørreskjemaet. Spørsmålet var formulert på følgende måte:

> *Husker du en spesiell episode fra fysikktimene eller en fysikkerfaring du har gjort deg i dagliglivet? Noe (eller noen) som har gjort deg nysgjerrig eller inspirert deg til å lære mer om fysikk?*

Dette spørsmålet ble besvart av 55 av studentene. Årsaken til at så få besvarte det, kan være at det innebar å formulere et eget svar og dermed ble sett på som mer arbeidsomt å besvare enn avkrysningsspørsmålene. En annen tenkelig årsak, er at studentene der og da ikke kom på noen spesiell episode eller fysikkerfaring å nevne.

For å utdype svarene fra spørreundersøkelsen, ble fem respondenter valgt ut for intervju med utgangspunkt i svarene de gav på spørreskjemaet som helhet. Disse vil i det følgende betegnes som informanter. I utvelgelsen ble det lagt vekt på å velge informanter som hadde ulike typer svar, for å få innsikt i flere forskjellige typer fysikkstudenter; en utvelgelse etter prinsippet ”maximum variation sampling” (Robson, 2003).

Intervjuene var semistrukturerte, som innebar at den nøyaktige ordlyden på hvert spørsmål ikke ble fastsatt på forhånd. Gjennom en intervjuguide ble samtaleemnene tematisk stilt opp med forslag til spørsmål omkring hvert emne. Intervjuguiden ble så tilpasset hver enkelt informant etter hvordan han eller hun hadde svart på det åpne spørsmålet i spørreskjemaet. Intervjuene varierte fra tjue minutter til tre kvarter i lengde. Intervjuene ble tatt opp ved hjelp av en digital lydopptaker, og deretter transkribert i sin helhet. I presentasjonen har vi gjort noen modifikasjoner av intervjusitater, for å bedre leseligheten.

I analysen av respondentenes svar på det åpne spørsmålet i spørreskjemaet, ble det utviklet fem kategorier induktivt fra materialet. Alle responsene ble kodet ved hjelp av disse kategoriene med dataprogrammet ATLAS. Her er det hver enkelt uttalelse som fungerer som analyseenhet, mens i intervjuene utgjør hver informant en analyseenhet. Intervjuene ble analysert ved hjelp av de utviklede kategoriene, samt kategorisering av interesse som individuell og situasjonell som beskrevet tidligere i artikkelen. Etter analyse av intervjuene med hver av informantene individuelt, er det gjort en tematisk analyse for informantene som gruppe.

Resultater fra spørreundersøkelsen

Resultatene fra det åpne spørsmålet i spørreskjemaet, viser at det er store variasjoner i hva studenter fokuserer på som inspirasjonskilde. Gjennom induktiv analyse ble svarene delt inn i fem kategorier;

- **Lærer og undervisning**; lærere som har vært spesielt inspirerende, eller spesielle episoder fra undersvisning
- **Fenomen**; ulike naturfenomener som har gjort inntrykk og skapt interesse
- **Nysgjerrighet**; en generell nysgjerrighet på og undring over naturen
- **Familie og venner**; foreldres og andre familiemedlemmers og venners innvirkning på interessen for fysikk
- **Media**; TV-programmer og tidsskrifter som tar opp fysikktemaer

Eksempler på responser innenfor kategoriene gis under presentasjonen av informantene som er fulgt opp med intervju. Tabell 1 viser antall svar innenfor hver kategori. Vi ser at læreren og undervisning er noe det fokuseres mye på, samtidig som mange av respondentene også kommer inn på erfaringer de har med forskjellige fysikkfenomener.

Tabell 1: Antall svar i hver kategori på det åpne spørsmålet i spørreskjemaet. Noen respondenter nevner flere forskjellige inspirasjonsfaktorer og de har dermed blitt registrert innenfor flere kategorier. Summen av svar overstiger derfor antallet respondenter (55).

Kategori	Antall svar
Lærer og undervisning	21
Fenomen	17
Nysgjerrighet	14
Familie og venner	8
Media	8

I svarene fra respondentene kommer det fram mye positivt om fysikkundervisningen på videregående skole, og for mange har fysikklæreren vært viktig for utviklingen av deres fysikkinteresse. Mange nevner også opplevelser de har hatt med fysikkfenomener i dagliglivet, som regnbuen og ting de har kunnet relatere til mekanisk fysikk. Enkelte trekker også fram eksperimenter de har vært med på i fysikktimene.

Noe av det respondentene skriver, peker på en iboende nysgjerrighet hos den enkelte. De har blitt inspirert som følge av en undring over naturen. Det er ikke et spesielt tema disse svarene peker på, men respondentene viser heller til en mer generell og altomfattende interesse for verden omkring dem. For noen ligger inspirasjonen i at ikke alt innenfor fysikk er kjent og utfordringen det ligger i å stadig lære naturen bedre å kjenne.

Media har også vært en viktig inspirasjonskilde for enkelte. Noen trekker fram personer, tidsskrifter og TV-programmer som har inspirert dem, mens andre nevner bøker om naturvitenskap som de fikk i barndommen.

Kun et fåtall av respondentene nevner familien som inspirasjonskilde. Oftest er det far som trekkes fram, enten gjennom sin utdannelse og jobb eller gjennom sin generelle interesse for naturvitenskap. Det er verdt å merke seg at de som nevner dette, utelukkende er kvinner. Det kan være nærliggende å anta at kvinnene kanskje i større grad enn menn behøver inspirasjon og støtte hjemmefra for å få interesse for å studere fysikk. Det er også mulig at menn er like avhengige av inspirasjon hjemme, men at de kanskje ikke fokuserer like mye på det som kvinnene når de blir bedt om å nevne sine inspirasjonskilder. I det følgende presenteres resultater fra en intervjustudie som vil kunne belyse disse og andre temaer nærmere.

Resultater fra intervjuene

I det følgende gis først en kort presentasjon av hver av informantene basert på intervjuene. Deretter blir informantene tematisk sammenliknet.

Presentasjon av informantene

Geir – nysgjerrig og samfunnsbevisst

I spørreskjemaet svarte Geir dette om hva som har inspirert han:

> ***Fysikktimer:*** *Lage is med flytende nitrogen. Morsom lærer i noen situasjoner. Måling av rilleavstand på CD-plate.*
>
> ***Dagliglivet:*** *Ting jeg har kunnet relatere til det jeg kan om mekanisk fysikk. Å se store konstruksjoner fascinerer meg.*

Interessen Geir har for fysikk, har oppstått av flere årsaker. Hans iboende nysgjerrighet har vært en viktig drivkraft og synes å ha vært til stede så lenge han kan huske. Han lurer på hvordan ting fungerer og lar seg fascinere av fly, tog, broer og bygningskonstruksjoner, og det gir han uttrykk for både i spørreskjema og intervju. Dette kan sies å være et karaktertrekk ved ham, og i så måte er Geirs naturvitenskapelige interesse av individuell art; den er en varig del av hans personlighet. Samtidig har interessen til Geir også blitt påvirket utenfra. Hans mange spørsmål om ting rundt ham, ble i barndommen rettet til foreldrene, som hjalp han med å finne svar på ulike måter.

Geir synes fysikk er interessant i seg selv, men i tillegg er det nytteaspektet ved fysikk som har gjort det så interessant at det er aktuelt for han å studere. Geir vil noe med det han lærer og ønsker at det skal ha en anvendelse som er nyttig for noen.

Thomas – kreativ og allsidig

Dette svarte Thomas om hva som har inspirert han:

> *Ein fagleg dyktig og strukturert lærar på vidaregåande skule. Eigne erfaringar og prosjekt på ungdomsskulen. Ein vil ved å blanda opplevingar med teori (vitensenter-pedagogikk) auka interessen for teorien. Kanskje fysikkundervisninga kan gjerast meir interaktiv (men helst utan å tapa noko fagleg).*

Thomas har mye han er interessert i, og han er slett ikke sikker på om fysikk nødvendigvis er det som er aller mest interessant for ham. Han sier selv at han på grunn av sin allsidighet ikke tror han er en helt klassisk fysikkstudent. Fysikkinteressen sin grunngir han med at det er et spennende fag og at det er utfordrende å prøve å forstå naturen rundt seg. Allerede fra før skolestart kan han huske at han lurte på hva fenomener rundt ham skyldtes. Denne vedvarende nysgjerrigheten ser ut til å være et karakteristisk trekk ved hans personlighet og kan sees på som en individuell interesse som ikke har oppstått av ytre årsaker. Samtidig legger Thomas vekt på at interessen trenger inspirasjon utenfra, og han mener lærere har hatt betydning for hans inntrykk av fagene han har hatt.

Nils – undrende og informasjonssøkende

Dette svarte Nils i spørreskjemaet:

> *Lest om moderne fysikk – astrofysikk, kvantefys.*

Nils fascineres av det ukjente ved fysikken. Han synes det er spennende at ikke alle naturens hemmeligheter er avslørt ennå og at man ved hjelp av fysikk kan lære mer om naturen. Derfor er det den moderne fysikken Nils liker best å lese om, nettopp fordi den ligger i forskningsfronten og fortsatt har ubesvarte spørsmål. Fysikkinteressen til Nils er like mye interesse for det ukjente som for fysikk i seg selv, og det er magien fysikk og matematikk har over seg som tiltrekker oppmerksomheten til Nils. Denne nysgjerrigheten på det ukjente og mystiske ved realfagene, er tydelig av individuell art og et sterkt karaktertrekk ved personligheten til Nils.

Den individuelle, sterke interessen Nils har for naturvitenskap, har fått ham til å oppsøke litteratur om dette på biblioteket. Han er også av den oppfatning at undervisning har vært viktig for videre utvikling av interessen hans. Ytre faktorer som bøker og undervisning har altså vært viktig også for Nils.

Espen – matteglad og puggelei

Dette svarte Espen i spørreskjemaet:

> *Har bare alltid vært interessert i hvordan ting henger sammen.*

Espen har vokst opp i en familie hvor mange har utdanning innenfor realfag, og han synes det er spennende med naturfenomener og å lære om hvordan naturen fungerer. Også arbeidsmetodene i realfagene passer godt for Espen, som klart gir uttrykk for at han ikke liker fag hvor det er mye lesing og pugging. Framfor å lese seg til kunnskap om naturvitenskap, foretrekker han å lære det gjennom regneoppgaver. Slik sett er ikke fysikkinteressen til Espen en interesse som preger livet hans utenfor skolen. Han liker naturvitenskap og å lære mer om sammenhenger i naturen, men har ikke behov for å oppsøke informasjon om det utover det han får gjennom skolepensumet.

For mange er det slik at realfagene oppleves som de vanskeligste fagene de møter i skoletiden og at andre fag er lettere. Espen har det helt motsatt; han synes realfag er lettere enn andre fag. Han sier at han alltid har vært glad i tall, og det synes å være litt uklart for ham hvorfor han har det slik. Realfagene er ganske enkelt det som passer til Espen som person, og interessen Espen har for fysikk er på den måten av svært individuell art.

Toril – lærevillig og formidlende

> *Veldig god matte- og fysikklærer på videregående skole - inspirerende. Har hatt foreldre som har forklart fysiske fenomener.*

Toril har en fysikkinteresse hun ikke helt vet hvordan har oppstått. På skolen har realfagene alltid vært de letteste og mest spennende fagene for henne. Som Espen liker Toril mye bedre å regne oppgaver enn å lese, og hun sier det er mye på grunn av realfagenes fokus på oppgaveregning at Toril liker de fagene så godt.

Toril mener også at foreldrene hennes har vært viktige i å utvikle hennes interesse for fysikk gjennom å gi henne forklaringer på ting hun har lurt på. Hun sier at foreldrene har betydd mer for fysikkinteressen enn det lærerne har gjort. Med unntak av én, har hun ikke vært spesielt fornøyd med realfagslærerne hun har hatt. Det har likevel ikke lagt en demper på realfagsinteressen hennes, for Toril har uansett hatt som mål å lære noe av den undervisningen hun har fått.

Tematisk sammenlikning av informantene: Hva har inspirert fysikkstudentene?

I det følgende gis en samlet framstilling av informantene med utgangspunkt i kategoriene som ble dannet fra den kvantitative undersøkelsen.

Lærere og undervisning

Det kommer tydelig fram i intervjuene at en god lærer viser engasjement for faget sitt, og alle informantene legger vekt på det i sin framstilling av lærere de har vært fornøyd med. En kjemilærer Thomas hadde i grunnkurs naturfag på videregående skole, vinklet alt inn på kjemi, også den delen av pensum som omhandlet fysikk og biologi. Det gjorde at Thomas fikk avsmak for kjemi og bestemte seg for ikke å ta det faget videre. Samtidig var mattelæreren på grunnkurs en engasjerende og spennende lærer som var en viktig inspirasjonsfaktor. Slike faktorer er av mer ytre art og har formet den allerede tilstedeværende interessen videre.

Geir og Thomas fokuserer på at læreren kan formidle fagstoffet på en morsom og spennende måte. Geir sier blant annet:

> *... ikke sant, når du går bakenfor naturlovene, ikke sant, så vet du ikke korfor. Så det var det han mente og prøvde å få oss til å forstå. Men... han hadde en litt artig måte å ordlegge seg på og litt sånne ting. Det var vel gjerne det.*

Geir synes altså det er inspirerende at læreren legger vekt på at vi bare kan beskrive hvordan naturen oppfører seg, og ikke så mye om hvorfor naturlovene er som de er. Toril og Espen er opptatt av at det skal settes av mye tid til regning og at kravet om rapportskriving skal være mindre i fysikktimene. Begge liker oppgaveregning, og det er mye på grunn av det at de trives bedre med realfagene enn andre fag. Fysikkfagets arbeidsmetoder er altså en viktig årsak til at de liker faget.

Nysgjerrighet

Fenomenene som informantene nevner som inspirerende, er ofte knyttet til eksperimenter som er gjort i fysikktimene. Praktisk arbeid i undervisningen synes derfor å være en viktig inspirasjonsfaktor, selv om det ikke er like godt likt av alle. Mye av grunnen til at Espen og Toril ikke likte forsøk i fysikktimene, var rapportskrivingen som ofte fulgte med. Det er altså ikke selve forsøkene som synes å være problemet, men etterarbeidet de skaper.

Flere av informantene påpeker at de har vært mer observante på fysikkfenomener i naturen etter at de har begynt med fysikk på videregående skole. Det mener det skyldes at før den tiden, visste de ikke så mye om hva fysikk var. Nils sier:

...eg merka det var når...etter at eg begynte med fysikk på skolen, så var det ting som oppga seg...eller eg tenkte på nye måter i forbindelse med fenomener rundt meg, både mekanisk og bølgefenomen og alt som er då. Lyset...lyd... Eg blei vel egentlig interessert i sånne... eller ble oppvakt på at det var fysikk rundt over alt, eller at alt var fysikk.

For Nils er det altså slik at fysikkfaget i skolen har åpnet øynene hans for at mye rundt ham kan relateres til fysikk. Fenomenene som han tidligere ikke hadde tenkt så mye over, ble satt inn i en ny sammenheng ved hjelp av fysikkundervisning.

For Thomas blir observasjoner av for eksempel ting som faller en medvirkende årsak til hans interesse for fysikktemaet mekanikk, siden mekanikken omhandler fenomener han kan forholde seg til i dagliglivet. Observasjoner av fysikkfenomener og undervisning i fysikk, ser altså ut til å kunne virke på hverandre begge veier. I noen tilfeller er det observasjoner som gjør at informantene blir interessert i undervisning om det, og andre ganger er det undervisningen som åpner øynene for flere observasjoner av fysikkfenomener.

Familiebakgrunn

Når informantene har lurt på noe innenfor fysikk, har de fleste hatt foreldre eller andre familiemedlemmer å spørre. Espen har familiemedlemmer med realfaglig utdanning, og han sier:

...hvis jeg ikke har fått til noe da, på ungdomsskolen eller videregående skole..., så har jeg jo fått hjelp, i hvert fall av pappa da. Så det er jo klart det, at da...da blir du jo kanskje bedre i det faget som foreldrene dine kan hjelpe deg litt i. Og da vil du synes at det er morsommere og.

Ikke alle informantene har foreldre med realfaglig utdanning, men Nils og Toril oppgir at foreldrene er interessert i naturvitenskap på hobbybasis. Nils beskriver dette som et forhold hvor han har kommet hjem og fortalt om hva han har lært, mens Torils foreldre synes å ha hatt en mer aktiv holdning til Torils læringsprosess. Begge har imidlertid kunnet snakke med foreldrene sine om realfag ut fra en felles interesse, og det har hatt innflytelse på egen læring og verdensanskuelse. Toril forklarer:

...når du har vokst opp, så har du alltid blitt forklart...altså du har fått vite at verden er større enn det du... enn det du bare ser. Og når du liksom... du tenker... du begynner gjerne å tenke på en måte som foreldra dine lærer deg å tenke. Så jeg tror nok faktisk at det har ganske mye å si. At jeg har hatt foreldre og sånn som har vært opptatt av at jeg skal skjønne ting som skjer.

Informantene har tidlig begynt å stille spørsmål til foreldrene sine og mener det har vært viktig for den videre interessen for fysikk. De har også foreldre som er opptatt av at barna skal få kunnskap og svar på det de lurer på, enten det gjelder å stille spørsmål til andre som vet svaret eller å finne svar gjennom bøker. Hverken Geir eller Thomas har foreldre med realfaglige yrker eller interesse, men likevel trekker begge dem fram som viktige i det å oppsøke informasjon. Geir sier:

...jeg har alltid spurt om ting, og da har mamma og pappa henvist til oppslagsverk som vi har, så jeg lærte meg ganske tidlig å bruke oppslagsverk. Og om de har gjort det med vilje eller ikke, det vet jeg ikke, men for meg, så tror kanskje jeg at det har vært god stimulans.

Det er mulig at informantene ville oppsøkt informasjon helt av seg selv, uten oppmuntring fra foreldrene. Imidlertid, og som Geir, Thomas og Toril sier, ser foreldrene ut til å ha vært en viktig pådriver i det å finne svar på det man lurer på, uavhengig av om de har realfaglig utdanning og interesse eller ikke. Generelt gir informantene uttrykk for å ha foreldre som synliggjør viktigheten av å tilegne seg kunnskap, og foreldrene tillegges større vekt i intervjuene enn de synes å ha fått i svarene fra spørreskjemaet.

Media

Det kommer fram av intervjuene at informantene ikke leser alt de kommer over av fysikkrelatert stoff i media. De følger i noen grad med i enkelte tidsskrifter og fjernsynsprogrammer, men det er ikke en aktivitet som preger hverdagen deres. På spørsmål om hva han følger med på i media, svarer Nils:

> *Eh, nei akkurat dei har eg ikkje så veldig mye befatning med. Men eg fylgjer jo med når det er noe...det er ikkje...ja, eg leser litt på Internett og sånn. Forskning.no og den slags, og har jo lest Illustrert Vitenskap. Men eg... eg har jo tilgang til... eg veit jo kor du finne informasjon...og seriøs informasjon av sånt man trenger å vite.*

Her sikter Nils til at han liker å oppsøke informasjon på biblioteket. Han har altså mer tiltro til boklig lærdom enn tidsskrifter og andre mediekilder, og dette er en kritisk holdning som også gjenspeiler seg hos flere av de andre informantene. De tar det ikke som en selvfølge at all informasjon de får gjennom media er riktig.

Thomas vektlegger det underholdende aspektet i media og synes det er bra med konsepter som kan bidra til å gjøre realfag mer interessant for folk flest. Han sier:

> *...Newton [et norsk populærvitenskapelig TV-magasin] syns eg er OK, det. Eg har sansen for det... å lage det litt meir spisbart, rett og slett. Og eg likte godt Newton når eg var...ja, fra eg begynte å se det på TV.*

Av de fem informantene er det Thomas som er mest opptatt av at media kan fungere som en interessevekker for barn og unge. Han ønsker at fysikk skal kunne gjøres interessant og spennende også for grupper utenfor fagmiljøet, og der mener han for eksempel TV-programmer og vitensentre er viktige bidragsytere. Dette er imidlertid ikke aktører som informantene mener har påvirket deres egen interesse i særlig grad.

Hva kjennetegner informantenes faglige interesse?

Alle de fem informantene uttrykker nysgjerrighet på fagfeltet fysikk og hva det kan fortelle dem om hvordan verden fungerer. Enkelte av dem uttrykker imidlertid stor interesse også for andre fagområder enn fysikk. Disse har ingen spesiell forkjærlighet for fysikk, men sier at de ønsker å studere det for å utvide kompetansen sin og fordi de mener det kan brukes til noe samfunnsnyttig. Allsidigheten ser for enkelte ut til å være et utslag av ønsket om å lære stadig nye ting, nærmest uavhengig av hva slags fagfelt det er snakk om. At tre av fem informanter har en slik faglig allsidighet, tyder på at fysikkstudentene ikke bare består av de som kun har interesse for realfagene.

Det er tydelig at fysikkstudenter er opptatt av å tilegne seg ny kunnskap og at de ser fysikkfaget som et velegnet fagfelt til å gjøre nettopp det. Informantene uttrykker interesse for realfagenes innhold, men også arbeidsmetodene innenfor disse fagene later til å passe dem bra. Blant annet er nysgjerrigheten som alle informantene uttrykker, viktig i naturvitenskapelig arbeid, og noen av dem liker spesielt fokuset fysikkfaget har på oppgaveregning. De sier at de ikke har den samme arbeidslysten i fag hvor det inngår mer lesing og pugging.

Enkelte av informantene inntar nærmest en rolle som detektiv i forhold til fysikken og begrunner sin interesse med at naturen fortsatt har mange uavslørte hemmeligheter. Informantene har på den måten en forskende holdning til fagfeltet og synes å være drevet av en naturlig indre motivasjon. Det varierer imidlertid hvor mye informantene synes fysikkfaget lykkes i å gi dem svar på det de lurer på, og synspunktene spenner fra de som synes det holder lenge med den informasjonen man får gjennom undervisning, til de som også bruker biblioteket for å finne svar i litteraturen som finnes der.

Hvordan og når har interessen oppstått?

På intervjuspørsmål omkring opprinnelsen til fysikkinteressen deres, nøler informantene og er usikre på hva de skal svare. Det er tydelig at de har vært interessert i fysikk lenge og at det ikke er så lett å sette ord på hvor interessen kommer fra. "Alltid" er et ord som går igjen både i spørreskjemaene og intervjuene, og informantene har få andre forklaringer på interessen sin enn at de nærmest må være disponert for den fra naturen sin side. De legger vekt på at de er nysgjerrige, at de liker å tilegne seg ny kunnskap og at de har hatt det slik så lenge de kan huske. I barndommen artet nysgjerrigheten seg som en undring over naturfenomener og et behov for å få forklaring på det, og siden har den utviklet seg til en fysikkfaglig interesse på høyt nivå. Hvordan det ene har ledet til det andre, er mer uklart for dem.

Det er interessant å merke seg at foreldrene blir tillagt stor vekt i intervjuene, på tross av at få av studentene kommer på å nevne dem i spørreskjemaet. Når informantene blir bedt om å snakke om foreldrene sine i intervjuene, kommer det fram at de har hatt stor betydning for det å finne svar på det man lurer på. Dette peker i retning av at familie og foreldre er svært viktige for fysikkinteressens utvikling. Informantene har hatt god støtte i det å tilpasse seg skole- og vitenskapsverdenen, slik Aikenhead (1996) beskriver den. De opplever ingen stengsler mellom sin egen livsverden og naturvitenskapens verden.

Andreas Krapp og andre forskere arbeider utfra et syn på interesse som noe som oppstår situasjonelt og utvikler seg til noe individuelt (Krapp, 2002). Det er altså en ytre hendelse eller erfaring som har gjort inntrykk og etterhvert blitt en varig og dyp interesse. Slik kan det ut fra våre informanters uttalelser også se ut til å være for fysikkstudenter. Interessen for fysikk kan spores tilbake til fysikkerfaringer i barndommen og foreldre som støtter opp om å søke kunnskap i oppslagsverk og ved å kontakte mennesker som ved mer om temaet det er spørsmål om.

Samtidig tyder vår undersøkelse på at fysikkstudenter ser ut til å være utstyrt med en nysgjerrighet og vitebegjærlighet som ikke har noen opprinnelse i ytre faktorer, men som er karakteristisk for deres personlighet. Denne nysgjerrigheten er åpenbart viktig i et fagfelt som fysikk. Fysikk handler om å utforske hvordan naturen oppfører seg og hvilke lovmessigheter den følger, og det er menneskets undring og kunnskapssøken som er årsaken til at vi vet så mye om naturen som vi gjør idag. Foreldre og barndomserfaringer med fysikkfenomener har uten tvil vært viktige for å gi næring til fysikkstudentenes utforskertrang, men den synes likevel å være en iboende egenskap og nokså uavhengig av situasjonelle betingelser.

Utfra intervjuene kan man, som vi har sett, finne både individuelle og situasjonelle trekk ved fysikkstudenters interesse. De har iboende egenskaper som gjør dem velegnet for fagfeltet sitt, samtidig som det er faktorer i familie og barndom som kan ha hatt stor betydning for interessens utvikling. De individuelle og situasjonelle trekkene synes med andre ord å være svært sammenvevd og forutsetter nærmest hverandre. Vår undersøkelse tyder på at det gjelder også generelt. Det er fem til dels svært ulike informanter som har blitt intervjuet, men interessen har hos dem alle vokst fram som følge av flere faktorer som har påvirket hverandre, og det er vanskelig å si hvilken faktor som har vært den viktigste.

Hvilken betydning har undervisning hatt?

Studentenes svar på spørreskjemaet gir inntrykk av at undervisning er en viktig inspirasjonskilde for fysikkstudenter. Læreren ser ut til å være spesielt avgjørende, og det er tydelig at dersom læreren evner å formidle fysikk på en spennende måte, er han eller hun svært viktig for utvikling av fysikkinteressen.

I intervjuene bekreftes viktigheten av undervisning, og informantene har klare meninger om lærerne de har hatt, enten de ble oppfattet som gode eller dårlige. Det er tydelig at undervisning engasjerer fysikkstudentene, uavhengig av om de har tenkt seg inn i bransjen selv, og de har en klar formening om hvordan de ønsker at fysikk skal formidles til dem. Det avgjørende synes å være at læreren selv er engasjert og at han eller hun evner å overføre sitt engasjement til elevene. De lærerne som har fått til det, har gjort et uutslettelig inntrykk på fysikkstudentene.

Intervjuene gir altså et inntrykk av at gode lærere har mye å si for fysikkelevers inspirasjon til å lære mer om fysikk. Det vil imidlertid ikke automatisk medføre at erfaringer med mindre gode lærere er til hinder for fysikkinteressen. En av informantene uttrykte at hun hadde fått sin fysikkinteresse på tross av og ikke på grunn av lærerne. Gode lærere ser altså ut til å være gunstig, men ikke avgjørende for fysikkinteressens utvikling.

Den viktigste funksjonen undervisning ser ut til å ha, er at den åpner øynene til elevene for hva fysikk egentlig er og hvor mye omkring dem som kan relateres til fysikk. Før videregående skole er det tydelig at forholdet til begrepet fysikk var noe diffust, og at undervisningen har gjort det mer håndgripelig og aktuelt for dem.

Hva har inspirert studentene til å velge et fysikkstudium?

Her tyder vår undersøkelse på at det er stor forskjell på de som har fysikk som sin hovedinteresse og de som har en mer allsidig faglig interesse utover realfagene. De som i hovedsak er fysikkinteressert, peker på arbeidsmetodene i faget, med oppgaveregning og entydige svar, som spesielt passende for dem. De tror også at realfag er det letteste for dem å studere, og de er ikke i tvil om at realfag er et riktig valg for dem. De andre har en mer generell interesse og kunne studert det meste, og det er samfunnsnyttigheten og jobbmulighetene som gjør at de velger fysikk.

Det er nærliggende å spørre seg hvorfor fysikkstudenter med en allsidig faglig interesse faktisk velger å studere fysikk. Er det noe spesielt ved fysikk som har gjort dem interessert i å studere det, eller føyer fysikkinteressen seg inn i rekken av interessen for mange fagfelt som kan gi bredere kompetanse? For en av informantene var det slik at han måtte velge mellom flere like aktuelle fagfelter da han skulle begynne å studere, og valget falt på fysikk mest på grunn av de varierte og samfunnsnyttige jobbmulighetene han syntes fysikk bød på. En annen grunngir valget av fysikk med at at han i større grad trenger utdanning for å lære realfag enn for eksempel språkfag, som han mener han lettere kan lese seg til kunnskap i på egen hånd. Det er altså ikke det rent fysikkfaglige som har vært viktigst i studievalget, men andre og mer praktiske hensyn har gjort at fysikk er det mest aktuelle for dem.

Troelsen (2006) har kommet fram til at interesse kan måles utfra hvilke konsekvenser interessen får for den det gjelder. I vår undersøkelse har informantene havnet på samme type studium, og selv om de uttrykker seg forskjellig om fysikkinteressen sin, er det endel fellestrekk som går igjen. Det er tydelig at fysikkstudenter legger vekt på frihet til å velge fag selv og varierte jobbmuligheter. Like viktig som at fysikk er interessant, er det at fysikken skal kunne lære dem noe nytt og brukes til noe samfunnsnyttig. Fysikkstudentene later til å ha et syn på fysikk som et praktisk verktøy som ved rett anvendelse kan gjøre verden bedre.

Konklusjon

Det er utfordrende å studere hvordan en interesse oppstår og utvikler seg. Menneskers interesser er nært knyttet opp mot deres omgivelser og deres erfaringsbakgrunn, og det er slett ikke åpenbart hvordan interessen begynte eller hva som har bidratt til å opprettholde og forsterke den for hver enkelt. Situasjonell og individuell interesse ser ut til å samvirke og forsterke hverandre.

I denne undersøkelsen har 55 studenter nevnt spesielle episoder eller fysikkerfaringer de selv mener har inspirert dem til å lære mer om fysikk. Det de skrev, har gitt et innblikk i faktorer som har vært viktige for disse studentene. I svarene på spørreundersøkelsen er det tydelig at episoder knyttet til fysikktimene på videregående skole og lærere de har hatt, er det første mange kommer på som viktig for dem. Dette understreker læreres betydning for motivasjon for naturvitenskapelige studier. Et stor andel studenter peker også på fysiske fenomener de tidlig har blitt fascinert av, eller henviser til nysgjerrighet som en egenskap ved dem selv. Forhold i familien tillegges mindre vekt.

Gjennom intervjuer med fem av informantene dannes et noe annerledes bilde. Her kommer det fram at familien, spesielt foreldre, har vært helt vesentlige i å oppmuntre studentenes nysgjerrighet i barndommen. Uavhengig av foreldrenes fagbakgrunn, ser de ut til å spille en viktig rolle i sine barns utvikling av en interesse for fysikk. Dette samsvarer med hvordan Lyons (2005) og andre har pekt på at familiebakgrunn er en viktigere forklaring på studenters utdanningsvalg enn det som framkommer ved spørreundersøkelser. Gjennom de fortellingene våre informanter kan gi ser det ut til at en slik sammenheng bunner i stimulans svært tidlig i barndommen, og dette kan bidra til å forklare at studenter ikke oppgir påvirkning fra foreldre som vesentlige for sine utdanningsvalg.

Både spørreundersøkelsen og intervjuene tyder på at en felles egenskap ved fysikkstudentene er at de har en sterk nysgjerrighet overfor verden og naturen omkring dem og hvordan den fungerer. De ser på fysikkfaget som noe som kan gi dem svarene de trenger for å forstå mer av verden. Fysikkstudentene ser videre ut til å i stor grad bli inspirert av det å stadig få lære noe nytt og at det ikke nødvendigvis er fysikkfagets innhold i seg selv som er den viktigste drivkraften. Fysikk er interessant for dem, men det er viktigst for dem å tilegne seg ny kunnskap, tilsynelatende nokså uavhengig av hvilket fagfelt det dreier seg om. Således bidrar valg av nettopp et fag som fysikk som fag til identitetsbygging og selvrealisering for disse studentene, uavhengig av hvilken nytte de ser for seg at faget skal kunne ha for dem selv eller samfunnet. Studentenes valg av fysikk som studievei framstår dermed ikke som instrumentelle valg slik undersøkelser tyder på at elevers valg av fysikk på lavere nivå i utdanningssystemet kan være (Lyons, 2005). Fysikkstudenter framstår i vår undersøkelse som opptatt av å realisere seg selv og sine evner. Selvrealiseringen oppfylles idet de får mulighet til å stadig få lære noe nytt og utvide horisonten. I ROSE-undersøkelsen fant man at en sentral motivasjon for 15-åringer i Norge og andre vestlige land, er det å kunne realisere seg selv og sine talenter, og man peker på at dette kan forklare bortvalg av naturvitenskapelige fag (Schreiner & Sjøberg, 2005). Vår undersøkelse tyder imidlertid på at også eldre studenter som har valgt et studium i fysikk ser på sitt studievalg som et selvrealiseringsprosjekt og ledd i sin identitetsbygging.

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Marianne Ødegaard er førsteamanuensis i naturfagdidaktikk ved Naturfagsenteret på Universitetet i Oslo hvor hun er forskningsleder. Hun er opptatt av naturfag som et allmenndannende fag, og hvordan blant annet drama kan bidra til dette. Hun er nå involvert i videobasert klasseromsforskning, hvor hun er spesielt interessert i læreres undervisningstilbud til elevene.

Nina E. Arnesen er ansatt på seksjon for Læring og lærerutdanning ved Universitetet for miljø- og biovitenskap. Hun er opptatt av hvordan elevene bruker samtalen i klasserommet til å konstruere sin naturfaglige forståelse, og hvordan læreren kan bidra til dette. Hun er også involvert i utviklingen av et verktøy som skal gi lærere mulighet til å bruke forskningsfunn for å reflektere over egen praksis. Arnesen har vært lærer på ungdomstrinnet i en årrekke.

MARIANNE ØDEGAARD
Naturfagsenteret, Universitetet i Oslo, Norge
e-post: marianne.odegaard@naturfagsenteret.no

NINA E. ARNESEN
Universitetet for miljø- og biovitenskap, Norge
e-post: n.e.arnesen@umb.no

Hva skjer i naturfagklasserommet? – resultater fra en videobasert klasseromsstudie; PISA+

Abstract

The aim of the PISA+ project is to pursue problematic findings in the international PISA survey. Through in-depth studies of classroom processes we wish to gain insight in how to understand and interpret the Norwegian results. The PISA+ project is a qualitative video study using observations and interviews. It includes six ninth grade classes followed for three weeks each in math, Norwegian and science. This paper focuses on the science lessons, and seeks to scrutinize which learning activities the students are offered, how the students can influence the lessons and to which extent they can learn science through own experience and talking science. We conclude that science teachers are quite open to student initiatives, and that the dominating learning activity is going through new subject matter in dialogue with the students. However, we saw very little inquiry science where students used practical experiments as a basis to actively talk science.

Introduksjon

Norsk skole har fått mye kritikk etter de siste års resultater fra de store internasjonale studiene PISA, - *Programme for International Student Assessment*) - og TIMSS - *Trends in International Mathematics and Science Study*. (Lie, Kjærnsli, Roe, & Turmo, 2001; Grønmo, Bergem, Kjærnsli, Lie, & Turmo, 2004; Kjærnsli, Lie, Olsen, Roe, & Turmo, 2004; Kjærnsli, Lie, Olsen, & Roe, 2007). Elevene skåret lavere enn gjennomsnittet for OECD landene i PISA, og de norske resultatene er nå de svakeste i Norden i alle tre fag som testes, naturfag, matematikk og lesing. Ikke minst urovekkende er det at norske elever er blant de med størst tilbakegang i skår fra PISA 2000 og til PISA 2006. Hvorfor har vi denne tilbakegangen? Hva er årsakene til at elever presterer dårligere på en undersøkelse som måler både elevenes begrepsforståelse og elevenes evne til å forstå og tolke naturvitenskaplige prosesser? De dårlige prestasjonene er blitt debattert, og det er mange forslag til forklaringer; alt fra bråkete elever, dårlig utdannede lærere, Gudmund Hernes' grunnskolereform i 1997 og endog PISA- og TIMSS- undersøkelsene i seg selv.

Prosjektet PISA+ (Prosjekt om Lærings- og UndervisningsStrategier i Skolen) ble etablert for å forsøke å forstå noen av de pedagogiske prosessene i norske klasserom i dag og se disse i forhold til PISA og TIMSS resultatene. Prosjektets overordnede forskningsspørsmål er:

- Hvordan kan vi forstå og fortolke det generelle prestasjonsnivået og mønstre i de norske PISA resultatene?
- Hvordan kan vi forstå de pedagogiske prosessene som former denne realiteten?
- Hvordan kan vi transformere noen av PISA-funnene til konkrete forslag for å forbedre norsk utdanning i et livslangt læringsperspektiv?

Forskningsspørsmål

Denne artikkelen vil ta for seg noen elementer av den naturfaglige delen av prosjektet. Vi ser på hvilke læringsaktiviteter elevene tilbys, og hvordan det legges til rette for at elevene skal skape mening i naturfagundervisningen. Bruk av språk i naturvitenskapelig samtale vil være fokus i en senere artikkel (Ødegaard & Arnesen, in press).

Her er våre forskningsspørsmål for denne naturfagstudien:

- Hvilke læringsaktiviteter får elevene tilbud om i naturfagundervisningen?
- I hvilken grad er elevene med og påvirker sin egen naturfagundervisning?
- I hvilken grad tilrettelegges det for at elever skal tilegne seg naturfaglig kunnskap basert på egne erfaringer og bruk av samtale?

Vi regner ikke med å kunne gi et entydig svar på hvorfor prestasjonsnivået i naturfag har gått ned, men håper, gjennom våre resultater, å kunne gi et bilde av hvordan undervisningen framstår og diskutere dette mot nyere naturfagdidaktisk litteratur og innføring av nyere arbeidsformer i skolen. Vi håper således på å bidra til en økt informert debatt om norsk naturfagundervisning.

PISA+

PISA+ er et videobasert forskningsprosjekt fra seks ulike klasserom i niende klassetrinn ved seks ulike skoler. Prosjektet omfatter matematikk, lesing og naturfag. Det er en kvalitativ dybdestudie som undersøker de pedagogiske prosessene bak resultatene fra tidligere PISA-studier (Kjærnsli et al. 2004; Lie et al. 2001) og evalueringsstudier av norske skoler (Klette, 2003; Schmidt, et al., 1996). Metodologien er inspirert av Evaluering av Reform 97 (Klette, 2003) og det internasjonale The Learner’s Perspective Study (Clarke, 2002). Forhåpentligvis vil PISA+’ resultater kunne tilby ny kunnskap som kan anvendes til å forbedre læring i skolen.

PISA+ fokuserer på å studere tilbudte læringsaktiviteter (handlinger) og erfarte læringsaktiviteter (mening). Derfor er prosjektet utformet som en videostudie med observasjoner og intervjuer av lærere og elever. Videoformatet gjør det mulig for oss å sammenlikne organiserende strukturer, aktiviteter og oppgaver i konkrete situasjoner på tvers av fag og klasserom. Gjennom intervjuene kan handlinger og meningskonstruksjon kommenteres. På denne måten kan vi på et overordnet nivå se mønstre og konsekvenser av handlinger som skjer på et klasseromsnivå, og forsøke å forstå grunnlaget for handlingen ved å gå i dybden på enkelttimer.

Bakgrunn for PISA+ naturfag

PISA+ tar utgangspunkt i resultater fra flere ulike studier. Disse har vært viktige for utformingen av prosjektet, hvilket datamateriale vi har valgt å fokusere på, og tolkning av resultater. PISA og TIMSS er begge store, internasjonale undersøkelser med kvantitative, komparative data. Evaluering av Reform 97 (Klette, 2003) og den internasjonale klasseromsstudien igangsatt i tilknytning til TIMSS 1995, *The Survey of Mathematics and Science Opportunities* study (SMSO) (Schmidt et al., 1996) er begge kvalitative klasseromsstudier, designet for å kunne si noe om typiske trekk ved blant annet norsk klasseromsundervisning.

Da PISA+ samlet inn sitt datamateriale, var læreplanen fra 1997 (L97) gjeldende. En av de rådende målsettingene med denne læreplanen var individuelt tilpasset opplæring, og læringssynet var i hovedsak konstruktivistisk: "Elever bygger i stor grad selv opp sin kunnskap, opparbeider sine ferdigheter og utvikler sine holdninger." (Kirke-, utdannings- og forskningsdepartementet (KUF) 1996, s.28). Når det gjelder naturfag, foreslår læreplanen at faget skal tilrettelegge for mange ulike aktiviteter, inkludert å sanse, observere, sortere, gjøre forsøk og gjøre feltarbeid (KUF. 1996).

PISA og TIMSS

PISA 2003 og 2006 viste at innen alle tre disipliner (lesing, matematikk og naturfag) presterte norske elever under OECD-gjennomsnittet, og dårligere enn i 2000 (Kjærnsli et al., 2004; Kjærnsli et al., 2007). Særlig har tilbakegangen vært stor i naturfag. Kjønnsforskjellene i lesing er blitt større i jentenes favør. I tillegg rapporterte elevene i PISA2000 om et svakt repertoar av læringsstrategier, svakt læringstrykk og høyt nivå av bråk og uro.

Også i TIMSS 2003 viste norske elever en markant tilbakegang i skåre fra forrige undersøkelse, som var i 1995 (Grønmo et al., 2004). De skåret riktignok litt over det internasjonale gjennomsnittet, men klart lavere enn land det er naturlig å sammenlikne seg med som Sverige, Nederland og USA. Over 70 % av de norske elevene skåret på nivå 1 (lavt) eller 2 (middels), hvor nivå 4 er mest avansert. I TIMSS 2007 fortsetter tilbakegangen svakt for elever på åttende trinn i naturfag (Grønmo & Onstad, 2008).

PISA-rapportene (Kjærnsli et al., 2004; Kjærnsli et al., 2007) og TIMSS-rapporten (Grønmo et al., 2004) antyder endrede lærer- og elevroller som en av flere mulige årsaker til elevers nedgang i resultater. Elever har fått større innflytelse gjennom økt elevmedvirkning, og man stiller dermed større krav til elevers selvregulerte læring. Man peker også på økt betoning av "ansvar for egen læring" og dermed økt bruk av elevsentrerte undervisningsformer som tverrfaglig prosjektarbeid og arbeidsplaner med selvstendig arbeid med oppgaver. Dette har igjen ført til endring av lærerrollen fra formidler til veileder. Lærere synes også å opptre med mindre autoritet. Det pekes på at læringsmålene i L97 inneholder en mengde formuleringer om hva elevene skal *gjøre,* men lite konkret om hva elevene skal oppnå ved aktiviteten, og at man undres på om elevaktivitetene knyttes til læring av fagstoff.

I TIMSS-undersøkelsen ble lærere spurt om bruk av arbeidsmetoder i naturfagundervisningen. At elevene følger med når lærer gjennomgår faglig stoff rapporteres som den hyppigst brukte aktiviteten. Dernest jobber elevene med oppgaver enten på egen hånd eller under veiledning av lærer. Norske elever arbeider imidlertid relativt sett oftere med oppgaver på egen hånd enn andre land, og lekser i naturfag følges i liten grad opp av lærerne i Norge. Eksperimentell undervisning derimot, meddeles å være mindre vanlig i Norge enn gjennomsnittet internasjonalt (Grønmo et al., 2004). Dette gjelder også for TIMSS 2007 (Grønmo & Onstad, 2008).

Både PISA- og TIMSS-rapportene legger vekt på at det ikke er hvilken undervisningsform som blir brukt som er viktig, men hvilken fagdidaktisk kvalitet den er preget av, for eksempel hvordan aktivitetene integreres i undervisningen og hvilken refleksjon hos elevene læreren legger opp til.

Evaluering av Reform 97 og SMSO

Evaluering av Reform 97 (Klette, 2003) er som navnet sier en evalueringsstudie av innføringen av den forrige læreplanen, Reform 97 (KUF, 1996). Et av delstudiene var å undersøke dominerende arbeids- og samhandlingsformer i norske klasserom. Studien er tverrfaglig, og vi kan derfor ikke lese ut av den hva som er spesielt for naturfag, men felles for fag på ungdomstrinnet er at det er lite variert arbeids- og organiseringsmønster. Den dominerende arbeidsformen er helklasseundervisning hvor lærer formidler fagstoff, dernest individuelt arbeid med oppgaver. Dette stemmer overens med det lærere og elever rapporterte i TIMSS 2003 og 2007. Interaksjonen mellom lærere og elever er preget av respekt og toleranse og med stor vilje til å se enkeltindividet. Klette viser til at det brukes lite tid til avrunding og oppsummering, og at de ulike aktivitetenes intensjoner derved blir uklar for elevene, noe som igjen fører til en svak sammenheng mellom "å gjøre noe og å lære noe". Hun har inntrykk av at det er "lite systematisk og oppsummert refleksjon rundt de ulike aktivitetenes læringspotensiale" (Klette, 2003, s.72). De ulike aktivitetene blir ofte gjennomført uten at de blir satt inn i en helhetlig faglig sammenheng.

SMSO-studien er en internasjonal klasseromsstudie som sammenlikner pedagogisk flyt i klasserom på tvers av land. Begrepet "pedagogisk flyt" viser til at naturfagtimer og andre timer har visse karakteristiske trekk og mønstre som er nedfelt i tradisjoner og kultur i et land, snarere enn bevisste pedagogiske valg. SMSO-forskerne skapte begrepet "karakteristisk pedagogisk flyt", som fokuserer på utførte pedagogiske strategier, jakten på det typiske og karakteristiske for et land og en erkjennelse av at faktiske klasseromssamhandlinger er mer intuitive enn analytiske for erfarne lærere. Mange valg er bygget på rutiner, erfaringer og antagelser. SMSO karakteriserte den pedagogiske flyten i seks land, inkludert Norge (Schmidt et al., 1996), og den gir viktig informasjon angående hvordan den pedagogiske flyten var i norske naturfagtimer for vel ti år siden. Typiske trekk var at man la vekt på elevenes akkumulasjon av korrekte faktakunnskaper og elevenes engasjement i øvelser, læringsaktiviteter og klasseromssamtaler. Det ble forventet at elevene forsto fakta gjennom å gjøre praktiske aktiviteter. Innholdet i timene var vanligvis lettfattelig, og ofte dreiet det seg om definisjoner eller beskrivelser av enkle begreper. Det var lite diskusjon i klassene om fagstoff. Lærernes spørsmål omhandlet oftere prosedyrer enn det substansielle innholdet. Timene var gjerne todelt på den måten at man begynte med en introduksjon til nytt stoff eller oppfølging av stoff fra forrige gang, og siden jobbet elevene uavhengig med øvelser, oppgaver eller utforskende oppgaver. Lærerne oppsummerte sjeldent resultater eller kunnskaper tilegnet i løpet av timen. SMSO viser til at elevsentrert undervisning kan føre til uklar framdrift og mål for undervisningen.

Meningsskapende naturfagundervisning

Vårt syn på læring av naturfag er basert på Vygotsky's perspektiv som hevder at læring oppstår i sosiale situasjoner, og at internaliseringsprosessen går fra sosiale kontekster til individuell forståelse (Vygotsky, 1978; 1986). Dette synspunktet, at de sosiale prosessene er vesentlig for læring, er allment akseptert på den naturfagdidaktiske arena (se Leach & Scott, 2003; Mortimer & Scott, 2003; Lemke, 2001; Carlsen, 2007; Wellington & Osborne, 2001). Man tenker seg at man møter nye ideer og begreper i sosiale situasjoner og at disse blir prøvet ut i samhandling med andre ved en rekke kommunikasjonsformer som tale, fakter, skriving, visuelle bilder og handling. En viktig del av den sosiale utprøvingen av ideer og begreper innebærer å sammenlikne egne forestillinger med andres forestillinger i tillegg til naturvitenskapens forklaringer (Scott, Asoko & Leach, 2007). Deltakerne reflekterer over og gjør seg opp en mening om hva som blir kommunisert i situasjonen. Mortimer og Scott (2003) beskriver for eksempel læring som både individuell meningsskaping hvor man rekonstruerer gamle og nye ideer, og dialogisk meningsskaping hvor ideer gis et språk i en sosial sammenheng. Her skapes mening ved at man får forståelse av faglig kunnskap; i første rekke begrepsforståelse. Vi har tatt utgangspunkt i arbeidene til Lemke (1990) og Mortimer og Scott (2003) når vi har laget vårt kategoriseringssystem for analyse av video fra våre naturfagklasserom.

Praktisk arbeid i naturfagundervisningen har vært i fokus lenge (Almendingen, Klepaker, & Tveita, 2003; Anderson, 2007; Jenkins, 1999; Kind, Kjærnsli, Lie, & Turmo, 1999; Klepaker, Almendingen & Tveita, 2007; KUF, 1996), både fordi det er viktig at elevene får innblikk i prosessdimensjonen ved naturvitenskapen (Isnes, 2005; Kunnskapsdepartementet (KD), 2006; Sjøberg 2004), og fordi det beriker elevenes læring om naturvitenskapelige fenomener og systemer (Dewey, 1936; Driver 1983; Scott, Asoko & Leach, 2007).

I det anglo-amerikanske naturfagdidaktikkmiljøet har ideen om "inquiry-based science teaching" (undersøkelsesbasert naturfagundervisning) vært rådende. Den anses som velegnet til både å veilede og belyse elevers forståelse av naturvitenskapelige prosesser og naturvitenskapelige begreper (Keys & Bryan 2001). Det er imidlertid ingen klar felles definisjon eller metodebeskrivelse for hva undersøkelsesbasert naturfagundervisning er. Utformingen vil nødvendigvis være avhengig av læreres tolkninger av hva undersøkelser er og andre faktorer i de lokale læringsmiljøer (ibid). Det finnes allikevel noen fellestrekk for denne type undervisning (Anderson, 2007):

- Den kjennetegnes ved at undersøkelser av autentiske spørsmål frambrakt av elevene er en sentral strategi for å undervise naturfag.
- Den refererer til elevaktiviteter hvor de kan utvikle kunnskap om og forståelse for naturvitenskapelige ideer, og likeledes en forståelse for hvordan forskere studerer naturen.
- Elevene arbeider ofte i grupper, og arbeidet de gjør kan ses på som bidrag til å løse felles problemer.

Engle og Conant (2002) har foreslått fire veiledende prinsipper for å fremme produktivt fag-engasjement. Med dette mener de at elever i samhandling med andre elever bidrar til diskusjonen om det emnet som er i fokus, gjerne gjentatte ganger med stor iver (fagengasjement), og at elevenes engasjement fører til intellektuell framgang (er produktivt). Ved å trekke inn både faglig innhold og samhandling, belyses læring samtidig som en kognitiv og sosial prosess. De fire kriteriene er;

1. å problematisere faglig innhold (lærere oppfordrer elever til å stille spørsmål, komme med kritiske kommentarer osv., i stedet for å passivt godta presenterte fakta)
2. å gi elever autoritet (gi elever mulighet til å innta en aktiv rolle ved å være en reell bidragsyter)
3. å holde elever ansvarlige overfor andre og overfor faglige standarder (elever forventes å sammenholde egne og andres oppfatninger med faglig relevante kilder)
4. å sørge for relevante undervisningsressurser (f.eks. nok tid til å gå i dybden, adgang til informasjon).

Disse fire prinsippene kan hjelpe oss å evaluere eller forstå læringsmiljøer som vil tilrettelegge for elevers produktive fagengasjement, hevder Engle og Conant (2002)

Både kjennetegnene for undersøkelsesbasert undervisning og prinsippene for produktivt fagengasjement synes å være gode kriterier for læring i naturfag som er forenelige med den rådende debatten om naturfagundervisning. Vi legger disse kriteriene til grunn for å diskutere meningsskapende naturfagundervisning i denne artikkelen.

Vi har her presentert bakgrunnen for PISA+ studien generelt og for naturfagdelen spesielt. Sammen med dette har vi presentert noen teoretiske perspektiver som bakgrunn for våre analysekategorier. Vi håper at analysekategoriene vil hjelpe oss til å karakterisere de involverte naturfagtimene i denne studien slik at vi kan prøve å forstå og diskutere dem i forhold til ideer om meningsskapende naturfagundervisning, for igjen å prøve å forstå bakgrunnen for resultatene fra PISA og TIMSS-undersøkelsene.

Datainnsamling

Våre primære informasjonskilder er naturfagklasserom på 9.trinn. Elevene er 14-15 år gamle. Studien inkluderer 6 klasser på 6 ulike skoler. Skolene er valgt ut slik at vi får variasjon i forhold til demografi og pedagogisk organisering. To skoler ligger i urbane strøk (skole 5 og 6), to ligger i landlige strøk (skole 1 og 3) og to ligger i forstedsområder (skole 2 og 4). To av skolene definerte seg selv som skoler med spesiell pedagogisk organisering. I dette ligger for eksempel utstrakt bruk av tverrfaglig undervisning med temadager (skole 5) eller høyt innslag av individuelt arbeid med bruk av arbeidsplan (skole 4). Hver klasse ble observert i tre uker. Datainnsamlingsperioden dekker til sammen nesten et helt skoleår.

I tabell 1 viser vi en oversikt over observerte/filmede økter i fagene. På skole 2, 3 og 5 filmet vi noen parallelle grupper og noen valgfrie økter med naturfaglig innhold. Derfor er det flere undervisningsøkter fra disse skolene. Ellers filmet vi alle naturfagtimer i den perioden vi var på skolen. På skole 4, hvor det var økt vekt på individuelt arbeid, var det naturlig nok færre undervisningstimer viet spesielle fag. I tillegg var naturfaglæreren syk, så en time ble avlyst. På grunn av en spesiell hendelse på skole 1, fikk vi bare observert én naturfagtime på denne skolen. Vi velger allikevel å ta den med i figurene som viser variasjon over skoler, men vi presiserer at sammenlikningsgrunnlaget med de andre skolene ikke er god.

Datamaterialet består av video, observasjoner og intervjuer. Vi har brukt tre kameraer; et fjernstyrt kamera som følger læreren, et som gir et oversiktsbilde av hele klassen og et som fokuserer på en liten gruppe elever, som regel to. I tillegg har vi gjennomført semi-strukturerte intervjuer med elever og observerte lærere, hvor informantene fikk mulighet til å kommentere videoene fra timene. Etter hver undervisningsøkt er to elever blitt intervjuet, nye elever for hver økt. Lærerne er intervjuet om en utvalgt økt i uka.

Elever og deres foresatte har gitt skriftlig samtykke til å delta i videostudien. Vi sørget for å ikke filme og intervjue de som ikke ville delta. Selv om noen av elevene tydelig gjorde seg til foran kamera, var ikke hovedinntrykket av klassene veldig forskjellig fra vanlig, opplyste lærerne oss om. Elevene bekreftet også at timene var slik de pleier å være, selv om noen hevdet at læreren kjeftet litt mindre.

For å analysere videoene har vi brukt software programmet *Videograph.* PISA+ prosjektet har en svært omfattende database av videomateriell (se tabell 1).

Tabell 1. Antall undervisningsøkter og antall minutter digitaliserte videoopptak av naturfagundervisning på de ulike skole.

	Naturfag	
Skole 1	1	42 min
Skole 2	9	194 min
Skole 3	11	445 min
Skole 4	3	153 min
Skole 5	16	677 min
Skole 6	5	254 min
	45	*1765 min*

Analysen

Software Videograph (Rimmele, 2002) er et program for å spille av og analysere digitaliserte videofiler. Ved hjelp av programmet kan man konstruere en visuell fargeprofil for hver økt, som synliggjør tidsbruken av de ulike aktiviteter slik disse er blitt kodet av forskerne i ettertid.

Felles koding for alle fag

De tre hovedkategoriene som ble brukt i vår fellesanalyse av alle fag, har i hovedsak fokus på læreren. De er: aktiviteter ved helklasseinstruksjon, læreraktiviteter ved individuelt arbeid og læreraktiviteter ved gruppearbeid. Kategoriene er gjensidig utelukkende. Hver kategori er igjen delt

Tabell 2. Kodeskjema for fellesanalysen av alle tre fag (naturfag, matematikk og norsk). Klette et al., 2005

Aktivitet ved helklasseinstruksjon	
Instruksjon – monologisk	*forelesning/fortelling/ lærer leser høyt osv.)(min. 3m.)*
Instruksjon – dialogisk	*bruke/mobilisere elevenes kunnskap v/ innføring i fagstoff*
Spørsmål/svar	*systematisk bruk av sp./sv for å sjekke ut/ kontrollere elevenes innsikt*
Helklassesamtale/diskusjon	*samtale der elevene kommenterer hverandres innspill*
Høytlesing	*elevene leser høyt fra en lærebok eller annen tekst*
Elevframføring	*elever framfører oppgaver/ dramatiseringer og tilsvarende*
Tilrettelegging	*lærer gir verbale/ikke verbale beskjeder om aktiviteter/ organisering/ materialbruk*
Irettesetting	*lærer irettesetter elever/ grupper av elever*
Ikke faglig kommentarer	*kommentarer av ikke faglig art*
Læreraktivitet ved individuelt arbeid	
Individuell veiledning	*lærer går rundt og gir hjelp/ støtte til enkeltelever*
Allmenngjøring av enkelt elever og /eller grupper av elevers spørsmål	
Kollektiv veiledning	*lærer veileder flere elever*
Går ut av rommet	*lærer forlater undervisningsrommet*
Ikke interaksjon	*lærer samhandler ikke med elevene; leser, rydder e.l.*
Læreraktivitet ved gruppearbeid	
Individuell veiledning	*lærer går rundt og gir hjelp/ støtte til enkeltelever*
Gruppe veiledning	*lærer går rundt og gir hjelp/ støtte til grupper*
Allmenngjøring av grupper av elevers spørsmål	
Ikke interaksjon	*lærer samhandler ikke med elevene; leser, rydder e.l.)*
Går ut av rommet	*lærer forlater undervisningsrommet*

inn i flere underkoder, (se tabell 2, Klette et al. 2005). Kategorier og koder ble utviklet av PISA+ gruppen på basis av kategorier brukt i tidligere klasseromsstudier (f.eks. Klette, 2003; Alexander, 2000; Galton, Hargreaves, Comber, Wall, & Pell, 1999) og våre data fra klasserommene.

Flere forskere var involvert i kodingen av timene. Reliabilitetstesten (ca. 10 % av materialet) viste 75 - 89 % overensstemmelse mellom de ulike koderne. Etter at undervisningsøktene ble kodet i Videograph, ble dataene overført til SPSS slik at man kunne sammenlikne og sammenfatte de ulike øktene. Kodingen som opprinnelig var oppgitt pr. sekund, ble nå transformert til minutter på den måten at den dominerende koden for hvert minutt ble gjort gjeldende.

Tabell 3. Kodeskjema for naturfag (Ødegaard og Arnesen, 2006).

Elevaktiviteter	
Noterer (fra tavla etc.)	*Elevene skriver ned det som læreren skriver på tavlen, lysarket e.l.*
Lese stille	*Elevene leser stille fra tekstbok eller annen skriftlig kilde*
Praktisk arbeid	*Elevene driver en praktisk aktivitet; i klasserom, laboratorium, ute*
Arbeide med oppgaver	*Elevene løser en oppgave individuelt eller i grupper. Oppgaven kan være gitt av lærer eller fra arbeidsplanen*
Følger med aktivt eller passivt	*Elevene følger med på / er engasjert i en felles aktivitet i klassen*
Bruk av IKT	*Elevene bruker IKT i læringen, dvs. at de sitter ved datamaskinen* *Mer enn halve gruppa bruker IKT*
Tilbudte læringsaktiviteter	
Aktivere tidligere kunnskap	*Relevant stoff fra tidligere timer eller elevenes egne oppfatninger mobiliseres med eller uten elevenes innspill*
Faglig appetittvekker	*Læreren gjør en demonstrasjon, viser frem konkreter eller bruker en historie, vits, fortelling e.l. for å motivere interesse for et tema*
Oppsummering av timen	*Timen oppsummeres gjennom monolog eller dialog med elevene for å tydeliggjøre temaet så langt, eller for å oppsummere hele timen mot slutten*
Gjennomgå arbeid fra timen	*Læreren går gjennom en aktivitet som har vært gjort i timen enten ved å snakke selv eller gjennom dialog med elevene*
Gjennomgå lekser eller annet egenarbeid	*Læreren går gjennom leksene/egenarbeid enten ved å snakke selv eller gjennom dialog med elevene*
Utvikle nytt fagstoff	*Læreren gjennomgår nytt stoff enten gjennom monolog, klasseromsdialog, elelr på annen måte*
Utvikle nye praktiske ferdigheter	*Læreren gjennomgår og følger opp nye ferdigheter knyttet til praktiske aktiviteter*
Klasseromssamtale	
Elevinitiativ	*Elevinitierte spørsmål eller kommentarer knyttet til faglig innhold eller praktisk gjennomføring.Omfatter også svar og kommenterer fra lærer/elever. Det kan gjerne være en serie spørsmål*
Lærer snakker	*Læreren presenterer nytt materiale monologisk (ikke nødvendigvis av så lang varighet) eller forklarer noe nærmere i forlengelsen av en respons til elevenes spørsmål.*
Lærerinitiativ	*Læreren stiller spørsmål, elevene besvarer for å mobilisere elevenes kunnskaper og refleksjon. Læreren kan evaluere eller kommentere svarene. Både spørsmål og kommentar kodes.*

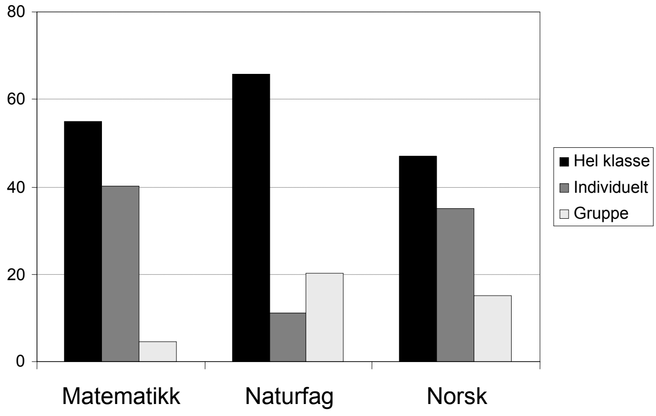
Koding av naturfagtimene

På grunnlag av felleskodingen, ble det utført ytterligere en koding på naturfagtimene. Hensikten var å analysere naturfaget i mer detalj for å si noe om hva som karakteriserer den pedagogiske flyten i timene. Felleskodingen indikerte at klasseromssamtalen er sentral i naturfagtimene. Derfor ble det lagt vekt på å karakterisere samtalen i klasserommet nærmere ved å kode hvorvidt det var lærer eller elever som tok initiativet. I tillegg ble elevaktiviteter og tilbudte aktiviteter fra lærer kodet. (se tabell 3) Kategoriene er utarbeidet med utgangspunkt i kategorier fra bl.a. "Talking Science" (Lemke 1990/2003) og "Meaning Making in Secondary Science Classrooms" (Mortimer & Scott 2003). Kategorivalget er også påvirket av våre observasjoner. De ulike kategoriene, f.eks. *tilbudte læringsaktiviteter* og *klasseromssamtalen* er her ikke gjensidig utelukkende, dvs. de forekommer og blir kodet samtidig, men kodene innenfor en kategori forekommer bare en om gangen. Analyser av språk- og begrepsbruken i PISA+ materiale vil presenteres i en kommende artikkel (Ødegaard & Arnesen, in press).

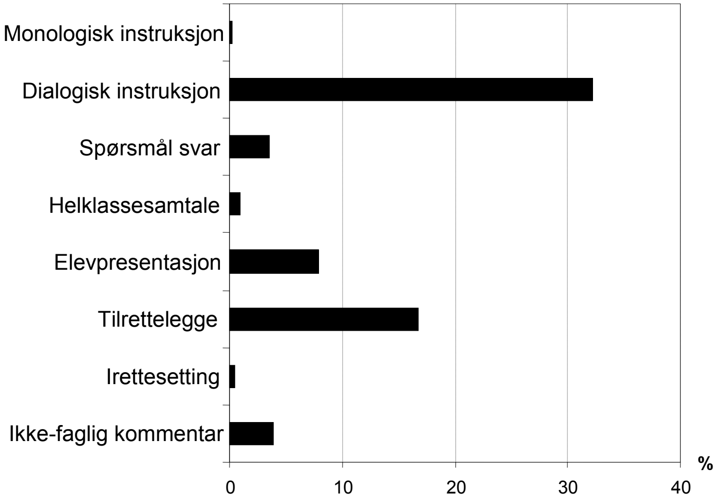
Resultater

Resultater fra felles koding for alle fag

Fra felleskodingen ser vi at naturfag har en særegen profil med stor vekt på undervisning i hel klasse (figur 1). Figur 2 viser at helklasseundervisningen har stort innslag av dialogisk instruksjon. I tillegg ser at læreren bruk en god del tid på å tilrettelegge og organisere undervisningen for elevene. Andelen gruppebaserte aktiviteter er mindre enn forventet i de observerte klasserommene ut fra tidligere forskning om laboratoriearbeid som en sentral del av et naturfaglig undervisningsrepertoar, og L97s vektlegging av elevaktiviteter. Se også Klette et al. (2007). De læreraktiviteter som er mest fremtredende ved gruppearbeid, er gruppeveiledning og individuell veiledning. Likeledes under individuelt arbeid er individuell veiledning og veiledning av flere elever, mest fremtredende. Ved både gruppearbeid og individuelt arbeid er imidlertid allmenngjøring av elevers spørsmål, altså at lærer deler spørsmål som flere lurer på med hele klassen, så å si ikke forekommende. Resten av tiden er læreren ikke i interaksjon med elevene.



Figur 1. Hovedformer av instruksjonsformat i de ulike fagene i prosent av kodet tid.



Figur 2. Fordeling på de ulike koder innenfor kategorien instruksjon i hel klasse i naturfag. Oppgis som prosent av kodet tid.

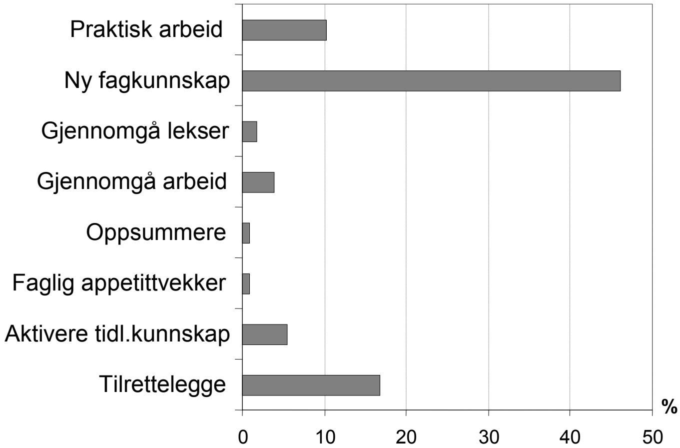
Resultater fra kodingen av naturfag

I det følgende blir resultatene fra kodingen av naturfagtimene kommentert. Det presiseres at analysene er foretatt ved å kategorisere observerbare hendelser og kvantifisere disse. Det er viktig å påpeke at lærerne som regel har gode begrunnelser for hver enkelt hendelse. Dette har vi data på gjennom observasjoner, samtaler og lærerintervju, men dette er ikke fokus for denne artikkelen (Se Ødegaard, 2008).

Tilbudte læringsaktiviteter

Vi ser av figur 3 at ved de observerte skolene blir det, som ventet, brukt mest tid på å utvikle nytt fagstoff. Dette kan innebære både teoretisk og praktisk kunnskap, holdningsarbeid i tema rusmidler, eller filosofiske og samfunnsmessige spørsmål i forbindelse med naturfag. Som nevnt under ”resultater fra felles koding for alle fag” blir mye av tiden brukt til organisering og tilrettelegging av elevenes arbeid. Dette er den nest vanligste aktiviteten i naturfagtimene. Blant annet blir mye tid brukt på at lærer forteller elevene hvordan de skal arbeide med oppgaver, både skriftlige og praktiske; hva og hvor de skal skrive; hvem de skal samarbeide med osv. Både tilbudet om nytt fagstoff og tilrettelegging er sterkt lærerstyrt, men har en dialogisk form. Lærer inkluderer ofte elevenes initiativ under utviklingen av nytt fagstoff.

Praktisk arbeid forkommer i gjennomsnitt en tiendedel av tiden, noe som var lavere enn vi forventet i forhold til læreplanens (L97) store fokus på aktiviteter. I mange år har det vært tradisjon for å i en god del kommuner å sette av ekstra tid til delingstimer en gang i uka i naturfag for praktisk arbeid. Ingen av de observerte skolene gjorde systematisk bruk av delingstimer i naturfag. Av tabell 4 ser vi at praktisk arbeid kun forkommer på tre skoler. Dette kan delvis skyldes at emnene som ble undervist ikke alltid gjorde det naturlig å inkludere praktiske øvelser, for eksempel temaet rusmidler. Det må også nevnes at en av skolene hadde økologiekskursjon og en dag på en gård mens vi var der. Dette materialet var det imidlertid ikke mulig å dokumentere på en slik måte at vi har kunnet ta det med i de kvantitative analysene. Hvis vi imidlertid ser på hver av de skolene som hadde praktisk arbeid mens vi var tilstede, er det allikevel ikke en veldig stor del av undervisningstilbudet.



Figur 3. Her vises en oversikt over lærernes undervisningstilbud til elevene i prosent av kodet tid. (Ikke-faglig aktivitet er ikke tatt med. Tallene for koden tilrettelegge er overført fra felleskodingen til dette diagrammet.)

Didaktiske prinsipper som å gi en faglig appetittvekker og introduksjon til et emne og å foreta en oppsummering av timens faginnhold og aktiviteter forekommer sjelden. Å bruke dette som et fast organiserende prinsipp, blir sjelden gjennomført. Ved et par anledninger så vi at en faglig appetittvekker ble brukt som innledning til et nytt emne, og det skapte positivt elevengasjement. Ved en skole ble et nytt emne om kroppen introdusert ved en undrende filosofisk diskusjon om hvor vi kommer fra, og hvordan vi har utviklet oss. Dette ble diskutert med stor iver fra elevenes side. På en annen skole ble emnet fotosyntesen introdusert ved at læreren ga elevene et solsikkefrø og viste dem en høy solsikkeblomst og ba elevene tenke over hvordan frøet kunne bli så stort.

Et annet naturfagdidaktisk prinsipp er å aktivisere tidligere kjent kunnskap. Dessuten vektlegges betydningen av å sammenlikne egne forestillinger med andres og se dem i sammenheng med naturvitenskapens forklaringer. I vårt materiale har vi kodet dette som *aktivisere tidligere kunnskap*. Koden forekommer en del, men stort sett er den en kort spørsmål-svar sekvens i hel klasse styrt av lærer. Ved kun ett tilfelle la læreren opp til at elevene skulle diskutere med hverandre hva de kunne om et emne fra før på generelt grunnlag. (”Hva husker dere om fotosyntesen?”)

Vi så sjelden gjennomgang av arbeid fra timen, se figur 3. Vi har observert at elever får ulike typer arbeid de skal gjøre på egen hånd eller sammen med andre i undervisningsøkten. Det kan være oppgaver fra boka eller lærer, skrive lab-rapport, skrive evaluering av gårdsbesøk, forberede foredrag eller liknende. De få gangene det forekommer gjennomgang av dette arbeidet i den aktuelle timen har elevene jobbet med en konkret avgrenset oppgave i undervisningsøkten. Heller ikke når elevene skriver lab-rapporter, blir arbeidet gjennomgått. Vi observerte ikke at det ble gitt eller gjennomgått hjemmearbeid.

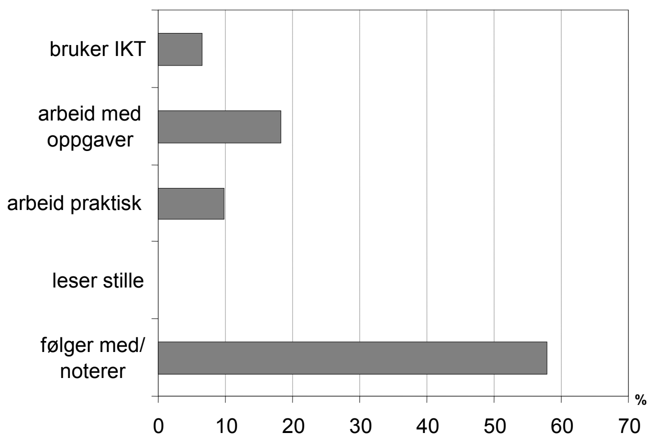
I tabell 4 ser vi variasjon i analysene for hver skole for kategorien *tilbudte aktiviteter*. Vi ser at felles for alle skolene er at gjennomgang av nytt fagstoff er en dominerende aktivitet sammen med tilrettelegging. For skole 1 gjelder bare én time.

Tabell 4. Variasjon i læreres tilbud om læringsaktiviteter ved de ulike skoler som inngår i studien. Tallene er prosent av kodet tid på hver skole.

Skole	Tilrettelegge	Aktiver tidligere kunnskap	Faglig appetittvekker	Oppsummere	Gjennomgå arbeid	Gjennomgå lekser	Ny fagkunnskap	Praktisk arbeid	Annet
1	12,6	2,4	14,6	0	9,8	0	60,6	0	0
2	8,5	11,9	0,2	0	6,7	9,7	57,7	0	5,3
3	23,9	4,9	0,5	4,7	0	0	30,1	13,8	22,1
4	24,1	11,2	0	0	2,9	0	37,9	0	23,9
5	15,4	3,1	0,8	0,1	3,9	0	51,3	15,8	9,6
6	15,8	0	1,6	0	5,3	0	45,1	13	19,2

Elevaktiviteter

Av figur 4 ser vi at den dominerende aktiviteten er at elevene følger med enten passivt eller aktivt; ved å svare på spørsmål, kommentere det som blir gjennomgått eller notere fra tavla. Dette gjelder for alle involverte skoler. Den nest største aktiviteten er at elevene arbeider med ulike typer oppgaver som ofte skal besvares skriftlig; enten ved å svare på spørsmål, skrive rapporter eller samle informasjon fra f.eks. bibliotek og internett. Koden *bruker IKT* blir brukt i de tilfeller hvor mer enn 50 % av klassen/gruppa har det som felles aktivitet. Dette skjer på tre skoler, hvorav en klasse jobber med en egen side utviklet av læreren på den lokale læringsplattformen (LMS) og to bruker Viten.no som er en nettbasert læringsplattform utviklet ved UiO og NTNU, http://viten.no.



Figur 4. Her vises en oversikt over elevenes læringsaktiviteter i prosent av kodet tid.

Klasseromssamtalen

Samtalen som foregår i hel klasse mellom lærer og elever eller elever imellom, har vi kalt for klasseromssamtale. Vi har skilt mellom når læreren snakker, altså hvor hele klassen har fokus på det læreren sier, og når læreren tar et initiativ til dialog med elevene enten ved å stille spørsmål, invitere til diskusjon eller liknende. Her kodes både lærerens initiativ og elevenes svar som *lærerinitiativ*. *Elevinitiativ* er når det er elevene selv som tar initiativet til å drive samtalen, ved f.eks. å stille faglig spørsmål, eller komme med nye kommentarer eller argumenter som gjør at klassesamtalen tar en ny retning. Både elevens spørsmål og lærerens svar kodes som *elevinitiativ* (se tabell 3).

Tabell 5. Ulike typer elevinitiativ med eksempler fra én undervisningsøkt i naturfag.

Elevinitiativ fra en undervisningsøkt Σ=26	Antall hendelser:
Om tavlebruk / notater: "Skal vi skrive det i boka vår?"	9
Om praktiske spørsmål / organisering: "Hvem skal være i den gruppa?"	7
Om praktisk arbeid: "Hva skal vi gjøre egentlig?"	3
Faglige kommentarer: Skal det ikke være hydrogen, ikke nitrogen?"	5
Om å skape mening: "Handler dette om fotosyntese?"	2

Koden *lærer snakker* gjelder i ca. en tredjedel av tiden, mens *lærerinitiativ* og *elevinitiativ* begge kodes i ca. en sjettedel av undervisningstiden, dvs. at både lærer og elever påvirker dialogdelen av klassesamtalen.

Som et eksempel har vi tatt for oss én undervisningsøkt og undersøkt nærmere hva elevinitiativene består av. Undervisningsøkten som her er valgt ut og analysert er en forholdsvis strukturert naturfagtime om fotosyntese med både teori og praktisk arbeid. Vi fant at sekvensene med elevinitiativ i hovedsak er knyttet til spørsmål om hvordan elevene skal utføre ulike oppgaver og handlinger, se tabell 5. Tabellen viser også at noen elevinitiativer er knyttet til det faglige innholdet i timen. Nærmere forskning omkring slike situasjoner vil gi oss mer informasjon om betydningen av dette initiativmønsteret. For eksempel, hvordan responderer lærere på de ulike elevinitiativene? Hvor mye naturfag bringes inn i praktiske spørsmål? Vi håper siden å få fram et samlet bilde av hvordan elevinitierte spørsmål kan påvirke undervisningen i naturfag.

Diskusjon

Læringsaktiviteter

Fellesanalysene for alle de tre fagene viste at naturfaget har et høyt innslag av helklasseundervisning sammenlignet med de to andre fagene. Dette betyr imidlertid ikke at læreren står og snakker hele tiden. Analysen av klasseromssamtalen viser at en stor del av den samtalen som foregår ved helklasseundervisning, er initiert av elever. Lærere er inkluderende og gir plass til elevenes kommentarer og spørsmål i undervisningen. Dette stemmer overens med det som ble rapportert i evalueringsstudien av Reform 97 (Klette, 2003). Anderson (2007) viser til viktigheten av at elever bidrar med autentiske spørsmål og medvirker til å løse felles problemer. Engle og Conant (2002) understreker betydningen av at elevene problematiserer det faglige innholdet ved å stille spørsmål og ved å være reelle bidragsytere. At det er et klima for å inkludere elevenes egne spørsmål og kommentarer gir et godt utgangspunkt for en meningsskapende naturfagundervisning. I vår studie er elevenes utspill ikke knyttet til det faglige innholdet i stor grad, men vi vet ikke nok om dette. Vi har sett eksempler på at elevinitiativer er knyttet både til praktiske og noe faglige spørsmål, og mest knyttet til beskrivelser. Ut fra dette mener vi at det er en utfordring for norske naturfaglærere å motivere og legge til rette for at elever skal beskjeftige seg mer med "hvorfor"-spørsmål. For å få mer kunnskap om elevenes påvirkning på den pedagogiske flyten og meningsskaping i naturfag, kreves mer detaljerte studier.

I figur 3 så vi at det var lite fokus på oppsummering og på å gjennomgå elevenes egenarbeid. Likevel viser figur 4 at elevene bruker en del tid på å arbeide med oppgaver. Hvorfor blir ikke dette arbeidet oppsummert eller gjennomgått? For å finne mer ut om dette så vi nærmere på de undervisningsøktene hvor vi faktisk hadde både *gjennomgåelse av arbeid* og *arbeide med oppgaver*. Det viste seg at i disse timene gjorde elevene oppgaver som var nært knyttet til dagens gjennomgåtte tema. Det var enten oppgaver læreren hadde laget eller oppgaver fra boka. Det som kjennetegnet det arbeidet elevene gjorde og som ikke ble gjennomgått eller oppsummert i samme time, var at det var knyttet til oppgaver som skulle evalueres senere; enten i tilknytning til prosjektarbeid, arbeidsplan eller labrapporter. Felles for alle disse læringsaktivitetene er at elevene får en forsinket tilbakemelding på sitt eget arbeid. Dette er ikke noe nytt når det gjelder lab-rapporter, men omfanget av prosjektarbeid og bruk av arbeidsplan har økt i de siste årene. Dette er arbeidsformer som krever stor grad av elevautonomi, og som ble innført delvis på grunn av påtrykk fra læreplanen (L97), og delvis for å møte utfordringene med individuelt tilpasset opplæring. Dette stemmer overens med refleksjoner gjort av Klette et al. (2003), Schmidt et al. (1996) og Kjærnsli et al. (2004, 2007). Vi ser at innføring av et arbeidsredskap for å løse en utfordring, kan skape nye utilsiktede problem. Arbeidsplanen som blant annet ble innført for å møte utfordringen om ansvar for egen læring og tilpasset opplæring, fører til at elevene får utsatt tilbakemelding på sine arbeider og dermed et lavt læringstrykk (Bergem, 2007). Nye arbeidsformer førte antagelig også til mangel på funn av koden *gjennomgå hjemmearbeid*, fordi elevene ikke lenger får det som tradisjonelt er kalt "lekser".

Vi fant at mindre tid enn forventet ble brukt på praktisk arbeid på våre studieskoler. Dette skyldes delvis tilfeldigheter som sykdom eller undervisningstema. Som nevnt, hadde ingen av de observerte skolene faste delingstimer knyttet til elevøvelser i naturfag, så gruppene som håndterte det praktiske utstyret, ble store. Dermed ble situasjonen fort uoversiktlig, og læreren brukte mye tid på å organisere gruppene og motivere enkeltelever til å gjøre noe. Det er kanskje et paradoks at læreren bruker mye mer tid på å fortelle elevene hva de skal gjøre (tilrettelegge) enn å gi elevene tid til egne aktiviteter?

Vi så lite systematisk bruk av de praktiske øvelsene som innfallsvinkel for faglig diskusjon hvor man knytter sammen teori og praksis i en utprøvende muntlig dialog. Dette støttes av funnet om lite bruk av empiriske referanser. Således går man glipp av noen gylne sjanser til å utnytte elevenes praktiske fagengasjement og samhandling til intellektuell framgang slik Engle og Conant (2002) beskriver det. Kan det være at i en stresset skolehverdag med høyt press på "å komme gjennom pensum" at det kan gå litt på akkord med praktisk arbeid, særlig hvis man ser det som et tillegg til og ikke et bidrag til det teoretiske pensumet?

Konklusjon/avsluttende kommentar

Undervisning og læring i naturfag er komplekse prosesser. I en omfattende videostudie som denne må man gjøre et utvalg i forhold til hva man vil fokusere på. De kategorier og skalaer man velger til sine analyser, vil påvirke det bildet man gir. Dette diskuteres i en egen metode-artikkel (Ødegaard & Klette, in press).

I denne artikkelen har vi valgt å fokusere på hvilke læringsaktiviteter elevene får tilbud om, i hvilken grad elevene er med og påvirker sin egen undervisning og i hvilken grad det tilrettelegges for at elever skal tilegne seg naturfaglig kunnskap basert på egne erfaringer og bruk av samtale.

For å oppsummere våre data kan vi si at de vanligste læringsaktivitetene i naturfagklasserommene vi besøkte var innføring av nytt fagstoff gjennom bruk av klasseromsdialog eller arbeid med oppgaver.Vi så lite varierte arbeids- og organiseringsmønstre, noe som er i tråd med tidligere funn (Klette, 2003; Schmidt et al., 1996) Praktisk arbeid er fortsatt sentralt, men det forekommer mye mindre enn vi hadde forventet (jfr. Almendingen, Klepaker, & Tveita, 2003). Elevenes arbeid er ofte knyttet til arbeidsformer som gjennomgåes og oppsummeres senere i undervisningsforløpet, f.eks. prosjektarbeid, arbeidsoppgaver på en arbeidsplan og elevøvelsesrapporter. Dette er ikke heldig ut fra didaktiske prinsipper om gjentagelse, jevnt læringstrykk og regelmessig tilbakemelding. Det kan se ut til at nye læringsaktiviteter som prosjektarbeid og bruk av arbeidsplaner har fått noen utilsiktede konsekvenser.

Lærerne er svært lydhøre for elevenes initiativ og inkluderer dem i undervisningen. Elevenes mening er viktig. Vi kan dermed si at elevene er med og påvirker sin egen naturfagundervisning. Vi kan allikevel ikke si at vår studie viser at elevene har en stor faglig påvirkning (se tabell 5). Imidlertid har den inkluderende atmosfæren i klasserommene potensiale i seg til å også omfatte aktiviteter med mer faglig elevmedvirkning (jfr. Anderson, 2007; Engle & Conant, 2002).

I vår studie så vi noe praktisk arbeidet, men det ble ikke brukt systematisk som samtalearena. Vi så heller ikke ellers mange gode fagsentrerte samtaler mellom elever hvor elever brukte egne erfaringer og språket for å oppnå faglig forståelse, eller faglige samtaler med lærer som hjelper til å skape bro mellom praksis og teori, slik vi har beskrevet over (Mortimer & Scott, 2003; Scott, Asoko & Leach, 2007; Wellington & Osborne, 2001).

Vi forventet ikke å kunne gi et klart svar på hvorfor prestasjonsnivået i naturfag har gått ned, men vi håper at våre studier bidrar til at vi ser på det som skjer i naturfagklasserommet på en litt ny måte. Ved å kvantifisere observasjoner trer andre mønstre fram enn de vi er vant til å se etter, for eksempel graden av beskrivelser i forhold til forklaringer. Vi håper på denne måten til å medvirke til at lærere og andre skolefolk engasjeres i en faglig debatt om norsk naturfagundervisning.

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Eva Björkholm is a University Lecturer in the profile area of Aesthetics, Technology and Learning at the Department of Education in Arts and Professions, Stockholm University. She works as a lecturer in elementary school technology education in the teacher education programme.

EVA BJÖRKHOLM
Department of Education in Arts and Professions, Stockholm University, Sweden
eva.bjorkholm@utep.su.se

Technology Education in Elementary School: Boys' and Girls' Interests and Attitudes

Abstract

This paper reports the results of an initial study investigating gender differences in interests and attitudes by pupils, aged 8-12 years, to school technology teaching in Sweden. The types of learning activities and content topics in technology teaching preferred by girls and boys were studied, as well as the differences regarding self-confidence in technology. The pupils' attitudes to technological professions were also investigated. The study was conducted in ten schools. A total of 256 pupils completed a questionnaire that was administrated during their school technology sessions. The analysis of the answers showed that a vast majority of both boys and girls experienced school technology as very positive. No gender differences in preferences for different types of content and activities were detected. The pupils' judgement of their own capability in the field of technology showed that both boys and girls considered themselves to be very competent. The boys felt, however, somewhat more certain about their competence compared with the girls. Gender differences were found in views of possible future occupations, but the pupils' views of future occupations in technology showed no significant gender differences.

Introduction

The fact that technology is strongly associated with masculinity can be seen in the male dominance that exists in engineering. In Sweden, during the academic year 2007/2008, the proportion of female students at the Master of Science in Engineering Programme was 25%, and in other higher education technical programmes it was 23% (SCB, 2009). By comparison, 85% of the students in health care and social work programmes were women. The proportion of women in the Master of Science in Engineering Programme has slowly declined over the past decade.

This raises the question of how much interest in technology there is among girls at the elementary school level. This article presents a study focusing on young girls' and boys' (aged 8-12 years) experiences of school technology teaching in Sweden. The pupils' perceptions of their own ability in terms of technology and their statements about possible future occupation will also be reported.

Background

As a starting point of this study, the division between male and female is understood as one of the strongest categorizations in our society, and our perceptions of what aspects of human life and society count as female and male vary over time and according to place and culture (Berner, 2003;

Connell, 2003). Gender is not static; it changes continuously and all of us are involved in this creative process, often without being aware of it. According to Harding (1986), gender is created in a process that takes place simultaneously at three different levels; structural gender, individual gender, and symbolic gender. Structural gender is concerned with organisation and division of labour by gender; individual gender focuses on the socially constructed individual identity; and symbolic gender is about the perceptions that our institutions express.

Male and female are often perceived to represent a dichotomy, i.e. what is regarded as masculine is the opposite of what is seen as feminine, and these opposites even exclude each other, such as active/passive or logical/illogical (Faulkner, 2001). Technical competence is a fundamental part of the cultural construction of certain masculinity, while women are associated with technical incompetence. Similarly, the relationship to technology and machines is an important part of men's cultural and social identity, while this could even be counteractive to the construction of feminine identity (Mellström, 2003).

Technology was introduced as a compulsory subject in the Swedish school system as a result of the 1980 curriculum for the nine-year compulsory school. Before designing our current curriculum for the compulsory education system, the preschool and the after-school centre, the Curriculum Committee (Läroplanskommittén) was given directives to pay attention to the issue of how different interests can be taken advantage of and promoted as early as possible in the education system. In connection with this, girls' interest in science and technology was specifically mentioned as an area the directives say that the school system has failed to address and develop (Directive 1991: 117, p.8).

The government bill that was introduced in 1992 (Prop. 1992/93: 220) points out that today's complex technological society demands that citizens have knowledge and understanding of technology, both as preparation for an active participation in society and as preparation for professional life. School technology teaching has a very important role in stimulating pupils', especially girls', interest in science and technology.

In the current syllabus of technology subjects for Swedish compulsory schools, the gender dimensions are presented in the account of the aim of the subject and its role in education, as follows:

> The attitudes of girls and boys to technology differ somewhat – as do traditional views on the role of girls as opposed to boys in technological contexts. One aim is that everyone is given the opportunity to consciously acquire all-round knowledge in the subject. (National Agency for Education, 2001)

A study on how girls and boys regarded science and technology in lower secondary school (Staberg, 1992), based on interviews and classroom observations, showed that the girls searched for contextual knowledge and had a more theoretical approach in their studies, compared with the more playful attitude of the boys. The girls criticised the lack of connection with reality, and sought understanding and cooperation. The science and technology subjects were seen as masculine by both sexes, and girls' interest in technology declined slowly but clearly from Grade 7 to Grade 9 (aged 13 to 15 years old).

Lindahl (2003) followed a group of 80 pupils from the age of 12 (Grade 5) until the age of 16 (Grade 9), and investigated their attitudes towards and interest in science and technology over time. Data was collected using observations, interviews and questionnaires. The results indicated that initial experience with chemistry, physics and technology in Grade 7 made the girls uninterested in learning more, but also showed that they were not so good in these subjects. Over the years, their interest remained at a very low level, but they felt slightly more competent. The boys also expressed lack of interest in technology, but were slightly more positive than the girls. Lindahl also investigated pupils' interest in other subjects. She noticed that interest in learning more in the social sciences and biology increased over the years for both girls and boys, as did their feeling of success.

In The Relevance of Science Education Project (ROSE), students' views about science and technology in education and in society are investigated. This was a large-scale international comparative study, involving 40 countries with over 40,000 students, about 15 years old (Schreiner & Sjøberg, 2004). Data were obtained by means of a questionnaire. The students were requested to indicate their interest in learning different science and technology topics, their experience with and views on school science and technology, and their views and attitudes to science and technology in society. Results from the ROSE project indicated that young people in all countries had rather positive attitudes to science and technology in society. The girls seemed, however, to be much more ambivalent than the boys and the differences were most dramatic in the richest North-European countries. The higher the level of development in a country, the lower the interest the students expressed in learning topics related to science and technology. Girls seemed to dislike school science and technology to a larger extent than the boys, and the gender differences were greater in more developed countries. While very few girls in most developed countries would like to get a job in technology, the boys were more positive, taking a somewhat neutral position towards the issue.

Weber and Custer (2005) have studied what content and types of activities in technology are most appreciated by female and male students aged 11-19 years old. The study consisted of two surveys involving a total of 348 middle school students and 311 students in high school technology education. The researchers found fewer differences between male and female students' scores for technology content than regarding the type of activity that was offered. The girls appreciated more design-oriented activities, while boys preferred activities that involved utilizing. The young girls in the study appreciated technology to a greater extent than the older girls.

Regarding pupils' judgement of their own competence, Staberg (1992) showed that girls in Grade 7-9 estimated their own abilities in science and technology as lower than what did boys. This finding is confirmed by other studies (Tallberg Broman, 2002). According to a survey carried out by the Association of Swedish Engineering Industries, with a sample of 354 respondents, this type of uncertainty about own abilities also tends to exist among female teachers in technology (Teknikföretagen, 2005).

Further, Skogh (2001) explored how girls aged 7-12 years old related to the technology they encounter in the home and school. Twenty-six girls from two schools were followed throughout their first five school years. Regular technical education was offered in only one of the schools. Data was collected by interviews, observations and questionnaires. Skogh found that girls' technological self-confidence was related to the extent to which they had positive experiences of the technical tasks they had to face, and to whether or not they had a firmly rooted definition of technology, i.e. a clear idea of what technology "is". Skogh believes that technology education is an effective way, through technical experience, to give more girls the possibility of shaping a "technical identity."

In a two-year research project, girls' participation in technology education in four school districts in Connecticut was studied (Silverman & Pritchard, 1996). Data were collected by classroom observations, focus group interviews, and surveys. The study reported that despite the fact that girls of 11 to 14 years of age appreciated technology education and had good confidence in their own technical ability; they did not voluntarily choose courses in technology and could not see themselves in a technical profession. Only a few girls were willing to challenge stereotypes about nontraditional careers for women.

Mammes (2004) shows, however, that both young girls' and boys' interest in technology is affected in a positive way by technology education. Four classes in the third year of elementary education were chosen for the study. Two of them were exposed to an intervention programme and the remaining two served as control groups. First, differences between the level of interest shown by boys and girls in technology were determined by a survey, and after exposure to technology education, a second survey took place. The results also showed that experiencing teaching of technology in elementary school can compensate for gender differences in interest in technology. Previous research (Roger & Duffield, 2000; Silverman & Pritchard, 1996) also indicated that teachers' awareness of and willingness to change their own gender stereotyped attitudes, expectations and actions is essential to change the girls' and boys' traditional approach to science and technology. The content of topics and way of working in technology and science education should also be relevant to the girls' experiences, interests and preferences.

It is difficult to extract a coherent view from earlier research about attitudes towards and interests in technology and technology education, as the question is very complex. Attitudes and interests may be influenced by many different things in school, as well as by social and cultural factors. Previous research about pupils' interest in technology education also often includes science. This fact complicates the drawing of clear conclusions about technology education specifically. However, the gender differences concerning how older pupils approach technology and technology education, which have been indicated in previous studies, have inspired me to investigate younger pupils' attitudes to technology and technology education.

The purpose of this article is to describe how girls and boys in elementary school are experiencing technology education in which they have participated in connection with the study. What content and types of activities in technology education do they appreciate? Do the pupils have confidence in their own ability in terms of technology? Can they imagine having a technical job, as an adult? How do the answers of the girls and boys differ?

Research design

The study was carried out in conjunction with technology lessons implemented by teacher trainees in technology during the teaching practice section of their teacher training programme. The data collection was conducted by ten technology teacher trainees who were engaged in teaching practice of two and three weeks in ten different Swedish schools. The participating schools were located in different types of residential areas in terms of economic, social and ethnic structure. Gender balance among the teacher trainees was unequal, but was representative of the prospective teachers in elementary school; 90% were women.

A total of 256 pupils in Grade 2-6 in elementary school (aged 8-12 years old) independently responded to a questionnaire about technology and teaching of technology. The proportion of girls and boys participating in the study was equal (129 girls/127 boys). The number of pupils per grade is shown in Table 1.

The extent of the pupils' previous experiences of technology in school varied. Some pupils had been offered some technology education, some pupils had undergone technological activities which had not been called technology, while others had not experienced any teaching of technology at all.

The content of the lessons varied to some extent, but common to all classes, except one, was that the pupils were working practically in some way with the following activities: design of vehicles (2 schools), mechanical models (2), structures using simple materials (2), their own inventions (1), other types of models (1), and taking apart and examining clocks and watches (1). The teacher trainees also indicated that they spent time during the lessons discussing technology and its

Table 1. The distribution of the number of pupils by grade, and gender balance.

Grade	Girls	Boys	Total
2	36	26	62
3	42	40	82
4	39	41	80
5	0	0	0
6	12	20	32
Total	129	127	256

influence on the environment (1 school), history of technology (1), the concept of technology (2), technical systems - communications, and water and sewage (2), and making study visits focusing on technology in the local environment (2). The number of technology lessons also varied between schools, but all pupils in the study had undergone technology teaching corresponding with the current syllabus of the technology subject.

After the technology lessons the pupils were surveyed and asked about what lesson content they had appreciated/not appreciated, what they perceived as difficult, and the confidence they felt regarding their own technical ability. The survey was conducted by the teacher trainees reading from a manuscript that I had made, after which the pupils wrote their responses to the questions themselves. The questions were formulated as six open questions (see Appendix) in order to facilitate access to a richer source of material than would be the case using multiple choice questions. The questions were deliberately simply formulated in order to get initial data for this first study. The teacher trainees made notes on the content and structure of their technology lessons, and enclosed these with the data collection.

The analysis of the responses to the questionnaire showed that pupils' statements could be grouped into different categories with each category representing a group of statements that had similar meaning. The categorization was made on the basis of responses to the questionnaire, with regard to the degree of appreciation/dissatisfaction with the technology lessons; the content of the lessons; the judgement of their own competence in terms of technology, and finally, to their plans regarding future occupations.

Results

The analysis of the responses to the questionnaire showed that the vast majority of pupils experienced the teaching of technology they just had undergone as very positive. In fact, 88% of the respondents to the survey used expressions such as "fun", "great" and "good". The gender differences were negligible.

> Fun, we learnt a lot. (Boy, Grade 4)
> It was fun. (Girl, Grade 2)

What did the pupils perceive as fun during the technology lessons? It was found that 12% of the girls answered that "everything was fun", while 16% of boys answered the same way. The most common responses given were of the type "build" and "make", such as "build a car" and "make a mechanical toy" without specifying what kind of activity they appreciated the most. Common to these responses, which were given by about 40% of the boys and girls, was that they described some type of practical work. Some examples of such responses are:

> It was fun that we could build something, and that we did not just read as in ordinary science lessons. (Girl, Grade 6)
> It was fun to build the car and then to test whether it worked or not. (Boy, Grade 4)

Design or aesthetic activities were not mentioned by the pupils to any great extent, and the percentage of girls and boys that brought this up was small. Similarly, things such as coming up with one's own solutions to problems and cooperation were mentioned only by a small percentage of the girls and the boys.

> To invent. (Boy, Grade 3)
> It was fun that we had to think a lot. (Boy, Grade 6)
> To build a car together with Erik. (Girl, Grade 4)

Study visits with a focus on technology in the local environment were mentioned by 15% of girls and 11% of boys.

> The museum was most fun, because there one could look at old cars and trains and things like that. (Boy, Grade 4)

To the question of what the pupils perceived as less fun during lessons, about 40% of the girls and boys responded "nothing was less fun". The activities that both girls and boys considered as less fun comprised the practical work (17% and 11% of girls and boys, respectively). These responses do not describe what specifically was less fun in this activity. However, difficulties in the functioning of the construction work were mentioned by a small percentage of both the girls and boys. Study visits in the local environment were mentioned as being less fun by a small percentage of both girls and boys.

> The visit to Torkälleberget Open-Air Museum, to stand still and listen. (Girl, Grade 4)

However, concerning the pupils' responses to the question about whether any specific content or activity was seen as difficult, a bigger difference between girls' and boys' responses was identified since 28% of the girls and 46% of the boys answered that "nothing was difficult". To a relatively high degree, when pupils listed something as difficult, it fell into the category of practical work (39% and 25% of the girls and boys, respectively).

> It was hard to attach the wheels and get them to roll. (Girl, Grade 4)
> To open the clocks. (Boy, Grade 2)

A small percentage of the girls and boys stated that coming up with their own solutions was difficult. The difference between the girls' and boys' answers about how difficult the technology lesson was perceived to be may signal a difference between boys' and girls' judgement of their own capability in the field of technology. This fact is also confirmed in the answers to the question "Do you think you are good at technology?" (Table 2). Here, 52% of the girls said that they were good or fairly good at technology, while 64% of the boys stated the same. However, 29% of the girls and 20% of the boys believed that they were not too good, while less than 10% of girls and boys did not think they were good at technology.

> From the beginning I hardly understood anything, but once I started, I was good. (Girl, Grade 6)
> I don't know. We just had a few lessons. (Girl, Grade 6)
> Yes indeed. (Boy, Grade 4)

Table 2. The pupils' answers to the question "Do you think you are good at technology"?

	Yes	Pretty good	Slightly	No	Other
Girls	39%	13%	29%	9%	10%
Boys	41%	23%	20%	7%	9%
Total	40%	18%	24%	8%	10%

The final question of the questionnaire was about how the pupils saw their future career plans and whether they, in this context, would be willing to work with technology. Here, 32% of the pupils responded that they could imagine themselves working with technology as an adult, while 58% answered "no" to this question. Most of the pupils did not want to work with technology, and the gender differences were relatively small in the whole group.

Table 3. The pupils' answers to the question "Can you imagine working with technology when you become an adult"?

	Yes	No	Yes and no	Other
Girls	29%	61%	5%	5%
Boys	34%	55%	1%	10%
Total	32%	58%	3%	7%

However, there were differences in responses between the pupils in Grade 4-6 compared with the pupils in Grade 2-3. While 36% of the girls and 42% of the boys in Grade 2-3 wanted to work with technology in the future, only 18% of the girls and 25% of the boys in Grade 4-6 felt that way.

The pupils were also asked why they wanted/did not want to work with technology. The pupils who indicated that they did not want to work with technology were asked to justify their standpoint. An equal number of girls and boys neither gave any answer nor responded that they wanted to work with something else. The most common reasons mentioned for wanting to work with technology were related to a positive experience of the current technology lessons. The gender differences were negligible. Some of the pupils referred to other factors, such as parents and personal interests, when explaining why they wanted to work with technology. Some examples are:

> Because I like to create things. (Girl, Grade 6)
> Because my mum works at Scania and my dad works as a plumber. (Boy, Grade 4)
> I have always wanted to become an inventor, and then one works with technology. (Boy, Grade 4)

The pupils who responded that they could not imagine a future job in the technical field were asked what they wanted to do as an adult. Here, a noticeable difference between the sexes could be distinguished.

The girls' interests were largely in the area of childcare/school/medical care/animal care, since 40% of girls' answers referred to this (compared to 6% of boys' answers). For the boys, 37% of their answers referred to the area of sports, for which the corresponding proportion of girls' responses was 11%. Occupations in technology, transport and science were only mentioned by boys, corresponding to 18% of the answers by the boys. Among the professions mentioned were mechanic and work with computers, despite the fact that the pupils answered "no" to the question about whether they wanted to work with technology in adulthood. This result may indicate that the pupils did not see the connection between technology and these kind of jobs.

I am going to work with cars. (Boy, Grade 2)
Mechanic or construction worker. (Boy, Grade 6)

Table 4. The pupils' answers to the question "What do you want to do as an adult"?

	Girls' Answer frequency	Boys' Answer frequency	Total Answer frequency
Don't know	12	12	24
Work with animals	22	3	25
Child care/school	10	0	10
Medical care	9	1	10
Fashion/home furnishing / cosmetics	14	0	14
Music, theatre	6	0	6
Shop/bank/law	9	5	14
Restaurant	4	3	7
Police/fireman	3	3	6
Journalist/author	2	4	6
Sport	11	25	36
Technology/science	0	12	12

Discussion

The results indicate that girls and boys to a great and equal extent experience school technology teaching as very positive. They also value the content and activities of the technology lessons in a similar manner. The pupils' responses show no gender differences in how they appreciate the teaching of technology, its content and type of activities. These findings differ from several earlier studies such as the ROSE project (Schreiner & Sjøberg, 2004), Staberg (1992), and Lindahl (2004) that indicate gender differences in interests and attitudes to science and technology education. The difference may partly be explained by the fact that the pupils in this study were younger than the participating pupils in the studies mentioned above. Staberg (1992) followed pupils aged 13 to 15 years, Lindahl (2004) studied pupils aged 12 to 16 years old and the participating pupils in the ROSE project (Schreiner & Sjøberg, 2004) were 15 years old. Mammes (2004) showed that the interest in technology of both young girls and boys was aroused and that technology education compensated for gender differences. The content and type of activities of the technology lessons studied by Staberg (1992) and Lindahl (2004) was not reported in detail, and may have been different from the lessons in this study. The content of topics and way of working in technology education has an important role in encouraging girls' interest in technology (Silverman & Pritchard, 1996; Roger & Duffield, 2000; Weber & Custer, 2005).

In this study, there was variation in the content, type of activities and the number of lessons that the pupils experienced, which makes it difficult to come to any general conclusions about the responses to questions dealing with pupils' attitudes to the content and type of activities. However, the pupils mentioned that the practical work was the most fun and also the most difficult activity in school technology teaching. This may reflect the fact that the technological subjects and their associated practical activities obviously are not taught in elementary school to a great extent, a point which has also been reported in a previous study (Teknikföretagen, 2005).

The results of the study can be understood in the three different levels at which gender is created according to Harding (1986). Structural gender, where occupations are divided up along traditional lines by gender, was reconstructed in the answers that the pupils gave in terms of the occupations they envisaged doing in the future. Professions that are traditionally perceived as masculine were not attractive to most girls because they do not strengthen the female identity, and the opposite conditions applied to boys in relation to traditionally female occupations. The individual gender is constructed simultaneously in this process. The pupils' responses also showed how the traditional male and female professions seem to have a contradictory relationship to each other; they are seen as representing a dichotomy (Faulkner, 2001). The pupils' perceptions of men's and women's careers were very strongly divided in the traditional manner. It is interesting to consider symbolic gender in this context. In this, the values and perceptions of technology that are instilled in young pupils at school are essential issues. Here, the female teacher trainees may have affected the answers in a more non-traditional direction, as long as they themselves displayed confidence in technology. An important aspect of the issue of gender equality concerns the potential and ability of students to manage and take over their own identity process. The solution to this problem involves developing both self-confidence and the ability to manage one's own process of learning.

Reflections on methodology

As a data collection method, and because of the type of simple questions used, the questionnaire had significant limitations in obtaining enough information about pupils' thoughts about teaching, hence additional interviews will be necessary for further investigations. The results indicate that the girls in the study seem to have lower self-esteem, compared with the boys, in the field of technology. This result is consistent with data from surveys of technology in the UK (Faulkner, 2001). Looking at it from another perspective, the differences between boys' and girls' judgements of their own technological capability may also indicate that the girls judge their own competence in a more realistic way.

The fact that the pupils evaluated the technology lessons implemented by the teacher trainees in the class, and also that the students led the common reading of the questions, may have influenced how the pupils answered the questions. The personal relationship between students and pupils may have influenced the pupils' responses in a more positive direction. The pupils may also have been exposed to some stress when they wrote their answers because the questions were read out separately and the class had to wait in between each one. The fact that even the 8-year-old pupils wrote their own answers could indicate a limitation in their answer method, as they had yet not fully mastered the skill of writing. These factors may have resulted in very brief answers from at least some pupils; a fact that causes difficulties in the analysis of responses. The questionnaire's "open" questions aimed, as I previously mentioned, to increase the possibility of obtaining richer empirical material. However, a consequence was that the categorisation of replies was more difficult to carry out. After repeated perusals and attempts at categorisation, I have nevertheless kept the categories set out here. My own role as a lecturer in the teacher trainees' teacher education programme may have influenced the results of the study, since these results are also the product of my own teaching.

Conclusion

Despite the methodological limitations described above, some conclusions may be drawn from the results of the study. They indicate that although there is a great variation in the amount and nature of technology teaching the Swedish pupils investigated have experienced, a vast majority of both girls and boys perceived school technology in positive ways. Furher, they experience themselves as being competent in technology, boys to a somewhat higher degree than girls. The main gender difference was found in how pupils look upon possible future occupations, where their responses show highly stereotype gender patterns. This remains a challenge with regards to both technology teaching and recruitment strategies.

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Appendix

Questionnaire

Grade: ___________

Girl ☐ Boy ☐

1. What did you think about the technology lesson/lessons?

2. What was fun?

3. What was less fun?

4. Was anything difficult? If so, what?

5. Do you think you are good at technology?

6. Can you imagine having a technology-centred career when you become an adult?

Yes ☐ Why?

No ☐ Why not?

If you answered no; what kind of work do you want to do as an adult?

Jakob Gyllenpalm is a PhD student in science education at Stockholm University. His thesis project revolve around inquiry and the nature of science in secondary school science education and teacher education. Per-Olof Wickman is professor in science education at Stockholm University. Sven-Olof Holmgren is professor emeritus in elementary particle physics at Stockholm University.

JAKOB GYLLENPALM
Stockholm University, Sweden
jakob.gyllenpalm@mnd.su.se

PER-OLOF WICKMAN
Stockholm University, Sweden
per-olof.wickman@mnd.su.se

SVEN-OLOF HOLMGREN
Stockholm University, Sweden
soh@physto.se

Secondary science teachers' selective traditions and examples of inquiry-oriented approaches

Abstract

This paper describes aspects of the existing tradition of practical work in secondary science education in Sweden, with a focus on inquiry-oriented teaching approaches. Twelve secondary science teachers were interviewed and asked to describe examples of their own teaching practices that they believed constituted inquiry-oriented teaching. The descriptions are analysed in relation to key components of inquiry as conceptualised in the science education literature. In addition, the teachers' way of talking about their own teaching in relation to inquiry is described and analysed. The results show a wide variety of teaching approaches that are associated with inquiry in different ways. Although inquiry is valued by many teachers, it is also problematic. We discuss the nature of the problems associated with inquiry by the teachers and the possible consequences of these for teacher education, in-service training and curriculum development.

Introduction

Inquiry has been promoted as a guiding concept of science education for more than one hundred years and continues to be so (DeBoer, 1991; I.A.P., 2005; National Research Council (U.S.), 1996; Rocard, 2007). In Sweden, the Royal Academy of Science initiated a school development programme in 1996 called Science and Technology for All (NTA) that is widely used today in Swedish primary schools and secondary schools for which it is being further developed. NTA is inspired by a curricular material developed in the US called Science and Technology for Children (STC), in response to the US National Standards call for Inquiry Based Science Education (IBSE) (www.nta.se). Given the level of efforts and funds dedicated to promoting inquiry, it is relevant to examine what inquiry and related approaches mean to Swedish teachers. Insights gained from studying inquiry in Swedish schools can also be relevant for science education in other countries, as issues related to inquiry are similar across many countries (Abd-El-Khalick et al., 2004).

The conditions and constraints for IBSE have attracted the attention of researchers for a long time. While some research has provided exemplars of successful teaching and learning through inquiry (Crawford, 2000), most reports have focused on identifying obstacles to reaching policy intentions (Anderson, 2007; Hume & Coll, 2008; Lederman, 2004; Rowell & Ebbers, 2004) and on teacher education (Windschitl, Thompson, & Braaten, 2008). Although widely discussed and researched in the US and UK, there is no well known equivalent of the expressions "inquiry" and "IBSE" in Sweden, which is part of the reason for this study. However, practical work in science education was introduced in Swedish upper secondary schools in approximately 1900 (Kaiserfeld, 1999). Löfdahl (1987) analysed physics laboratory tasks in secondary and upper secondary schools in Sweden between 1962 and 1980 and found almost no examples of inquiry, as the term is used in this paper. Hult (2000) concluded that closed as opposed to open-ended laboratory work is the rule in higher education. More recently, Högström, Ottander and Benkert (2005) interviewed eleven secondary teachers about their goals with laboratory work in science. They found that the most common goals included confirming theory and creating a need and motivation to learn theory.

The development of curriculum materials and reform efforts has shown that for these to contribute positively, teachers' voices and existing school cultures must be taken into account (Keys & Bryan, 2001; Trumbull, Bonney, & Grudens-Schuck, 2005). Otherwise, school development projects may be hindered by participants holding different, unarticulated and unchallenged assumptions about key issues (Fredrichsen, Munford, & Orgill, 2006; Trumbull et al., 2005). Research into the history of school subjects shows that different selective traditions develop, which can be understood in terms of how content and teaching methods are habitually selected (Sandell, Öhman, Östman, Billingham, & Lindman, 2005; Williams, 1973). Like other established traditions, selective traditions are often largely unexamined by its members (Dewey, 1930). This may result in new influences such as a new curriculum or curricular material being interpreted and used within the existing tradition, and thus transformed into something old and familiar. Avoiding this requires active reflection on the existing tradition, and a prerequisite for this is that the traditions are first made explicit. In addition, teachers may already have functional teaching approaches relative to the aforementioned policy documents. Nonetheless, according to Keys and Byran (2001), there is a lack of research on inquiry-oriented approaches that are designed and used by teachers without the involvement of educational researchers. The present study is an attempt to make the existing tradition of practical work explicit in respect to key dimensions of inquiry described in the science education literature. It aims to clarify the debate on curriculum development as well as assist teachers to discuss their own teaching by introducing a taxonomy of instructional approaches. In particular, we have focused on the following three research questions:

1. What do secondary science teachers describe as their own examples of inquiry-oriented teaching approaches?
2. What affordances, problems and contrasts do the teachers describe in relation to inquiry-oriented teaching approaches?
3. How are these examples related to conceptualisations of inquiry in the science education literature?

Method

Twelve teachers were asked to bring an example from their own teaching that they thought represented an inquiry-oriented approach (IOA) (*ett undersökande arbetssätt* in Swedish) for teaching science. The instances of IOA were rather loosely defined intentionally as instances in which the students themselves find out answers about nature through some kind of methodical study, experiment, field observations or similar. The idea was to avoid placing too many constraints on what might count as inquiry. Furthermore, the reason for asking the teachers to bring an authentic example from their own teaching was to situate the interviews in the teachers' actual classrooms in order to avoid the inclusion of too much romancing in their accounts (Kvale, 1996).

Interviews

To obtain data on the teachers' examples of IOA, semi-structured interviews were used. To ask a predefined series of questions about how they use inquiry in their teaching would suggest certain types of answers and exclude others; this was considered too guided - especially since the aim was to obtain a broad description of the existing tradition. Cobern and Loving (2000) used a similar approach to the one adopted here in a study on teachers' enacted worldviews.

The interviews took place at each teacher's school. During the interviews, the first author asked the teachers to describe their examples and used a template with terms and categories that were considered important and relevant to inquiry in school science (see the section *Inquiry and learning outcome emphases*). The intention was to ask the teachers about these terms in connection with the examples they supplied (Kvale, 1996). Even though a specific set of questions was not used, the following questions served as a tacit guide during the interviews:

1. What is the example about?
2. How is this example motivated as a part of this teacher's teaching?
3. What are the students supposed to learn?
4. How is this example related to key dimensions of IOA?

This heuristic method was intended to produce an understanding of the teachers' examples without losing track of the context of school science and their own way of describing their teaching. However, as the researcher focused on aspects of inquiry during the interviews, in terms of both scientific investigations and as a teaching approach, some teachers recalled additional examples that they believed were more relevant.

The recorded interviews were transcribed and then condensed into first-person narratives with a focus on the research questions of this study. Care was taken to retain the original wording of the teachers during the interviews, while also making it a more readable text. In some narrative quotes the wording may seem slightly unusual. This is due to the fact that they are an attempt to stay close to the spoken language of the interview setting, and is not an artefact of the translation into English. The narratives were read by the teachers and then revised and edited according to their suggestions. This increased the validity by enabling the teachers to omit errors and ensuring that these individuals felt that they could stand for the statements.

Participants

As the study was both explorative and qualitative, diversity was considered more important than a random selection of participants (Neuman, 2005). In order to achieve diversity in terms of different kinds of experiences and backgrounds, the selection was based on three criteria: years of experience as a teacher, equal number of men and women and schools in a variety of neighbourhoods. Twelve teachers with teaching experience ranging between 5 and 30 years were interviewed. The teachers' experiences also varied with regard to inquiry-oriented in-service training.

Analytical framework

The term "inquiry" has been used to refer to at least three different ideas within science education: a set of skills to be learned by students, a conceptual knowledge of the characteristics of doing science and a pedagogical strategy (Bybee, 2000). Below, we describe key dimensions of inquiry as conceptualised in influential policy documents, curricula and the science education literature in terms of learning outcomes and instructional approaches.

Inquiry and Learning Outcome Emphases

Inquiry as a learning outcome is one of many learning outcomes specified by curricula in various forms and with different emphases. The Swedish national curriculum for secondary school science includes learning outcomes in terms of knowledge about scientific investigations as well as abilities to plan and conduct scientific investigations (Swedish National Agency for Education, 2009). In this study we use three categories of intended learning outcomes to analyse the examples discussed with the teachers. The first two are specific to inquiry and IBSE, while the third is generic in science education.

A) Learning to do inquiry
B) Learning about inquiry
C) Learning science subject matter

Learning to do inquiry (A) includes a set of skills that students need to master to "do science", but it also goes beyond mere process skills. Learning to do inquiry also means combining these processes with scientific knowledge, reasoning and critical thinking to develop scientific knowledge (Lederman, 2004). We choose to focus on only two specific aspect that have been described as fundamental by influential policy documents, teacher handbooks and educational research: 1) learning to pose questions and formulate hypotheses that can be investigated in a scientific manner and 2) learning to design, plan and carry out a scientific investigation in relation to a research question or hypothesis (Eggen & Kauchak, 2006; Lederman, 2004; National Research Council (U.S.), 2000).

Learning about inquiry (B) includes knowing how scientific knowledge is developed. Knowledge about inquiry would, for example, include knowing that scientific investigations are derived from a question or hypothesis, and that answering scientific questions involves empirical data. It also includes understanding that there is no single scientific method, that questions guide the methods used by scientists and that these vary greatly. Knowledge about inquiry would, for example, also include that control of variables (i.e. a controlled experiment) is a particular scientific method used to study causality, and that this differs from studying correlations (Lederman, 2004). Knowledge in both category A and B involves acquiring a language in order to talk and communicate about investigations and their results. Knowledge about inquiry may be useful for doing inquiry and are not merely propositions to be remembered.

Learning science subject matter (C) basically refers to learning the conceptual products of science - the textbook explanations, models and concepts. This learning outcome is generic and not connected to IBSE in any specific way. The subject matter of a science curriculum can be structured in different ways (Roberts, 1982). In this paper, we group all categories of curricular emphases or goals not explicitly associated with inquiry in category C, including e.g. learning about socio-scientific issues.

Inquiry as an Instructional Approach

To describe the teachers' examples and differentiate types of instructional approaches, we constructed a taxonomy of instructional approaches (Table 1). This is inspired by the work of Schwab (1962) and Domin (1999), and it is based on the division of a scientific investigation into three parts: question, method and results. In investigations as instructional activities, these parts can either be open or given. Schwab used these to define the concept of degrees of freedom from 0 to 3 for practical work, and Domin used a similar scheme to define the instructional approaches: inquiry, guided-inquiry/discovery, expository and problem-based. Below, we comment on each instructional approach.

Table 1. Taxonomy of instructional approaches based on the dimensions of question/method/ result that can be either open (O) or given (X)

Degrees of freedom	Type of instructional approach	Question / Problem	Method	Answer / Result
0	Expository	X	X	X
0	Discovery	X	X	X
1	Problem-Based	X	O	X
1	Guided Inquiry	X	X	O
2	Inquiry	X	O	O
3	Open Inquiry	O	O	O

Expository Instruction: This is probably the most common laboratory instructional approach in which students follow directions to reach a predetermined outcome, e.g. measuring a natural constant in physics. This is often done by using a "cook book" style of instruction.

Discovery Instruction: This approach has the same degree of freedom as *Expository Instruction,* but the difference lies in how it is staged by the teacher - the dramaturgy one may say. The teacher leads the students on so they feel as if they have "discovered" a particular phenomena or arrived at a specific notion or need for a specific notion. Here we use the term "discovery" differently from Domin (1999) who equated it with "guided inquiry".

Guided Inquiry/Inquiry/Open Inquiry Instruction: The main characteristic of these approaches is that they are framed by some sort of question for which an answer cannot readily be found in a textbook. In *Inquiry Instruction,* the question is given by the teacher, whereas in *Guided Inquiry Instruction,* both the question and the method are provided by the teacher. In *Open Inquiry,* an important part is to formulate a question that can be investigated.

Problem-Based Instruction: The main difference from the various types of inquiry is that the question and result melt together in the formulation of a problem to be solved. There are usually different ways or methods of solving the problem.

Sometimes concepts like "inquiry learning" or "discovery learning" are used to refer to some vaguely defined psychological process of learning. What is usually meant is "learning when doing inquiry" or "learning when making discoveries"; therefore, we feel that it is more honest and less confusing in this context to reserve terms like "inquiry" and "discovery" to refer to instructional approaches rather than to modes of learning.

Obviously, this simple taxonomy is a very crude map of different types of instructional approaches. The different types of instruction may follow each other in a sequence of teaching with different emphases. Moving between different approaches can be thought of as more or less continuous or sometimes in terms of discrete steps. However, its usefulness lies in its simplicity as a tool for analysing teaching approaches. The taxonomy was applied to all of the major examples of teaching units discussed during the interviews. Each interview was read by the two first authors to reach a consensus about the coding. The application was straightforward with few exceptions (see *Results*).

Teachers' Own Descriptions of IOA

In addition to using the taxonomy of instructional approaches, two methods of analysing the teachers' own ways of describing IOA were used. First, the narrative summaries were coded into three categories: statements referring to positive associations with IOA, problems associated with IOA and descriptions of instructional approaches. Positive and problematic associations with IOA were summarised and then sorted into secondary categorisations consisting of groups of statements that had some features in common. This led to a re-evaluation of some statements as either positive, problematic or neither. All of the narratives included statements that were relevant to these categories.

Secondly, repeated readings of the narratives and the original interview transcripts suggested that the descriptions of instructional approaches could be coded into two subcategories: instructional approaches associated with IOA and those in contrast to these. Nine out of the twelve narratives contained descriptions of instructional approaches, which supported this subcategorisation. For the remaining three interviews, the original transcripts were reread to determine if any descriptions of instructional approaches had been missed in the compilation of the narratives. However, none were found. The descriptive statements were isolated, and from these, a table of descriptors of instructional approaches was compiled.

Results

Teachers' Outcome Emphases and Instructional Approaches

Here, 6 of the 18 main examples discussed during the interviews are presented in the format of condensed narratives. They are chosen to represent the range of the different types of examples encountered. Each example is commented on with particular reference to the learning outcomes A, B and C, (i.e. learning to do inquiry, learning about inquiry and learning through inquiry), and instructional approaches. The names of the teachers are pseudonyms.

> *Christian:* Two laboratory tasks that we recently did [in grade 8] had to do with how you can recognise starch and how the saliva affects starch in the food. The students worked with each laboratory task for perhaps 20 minutes. What I want them to learn is that you can show the presence of starch with iodine, and reduced sugars with Trommer's test, and that starch is decomposed into sugar by a substance in the saliva called amylase. It is also slightly connected to biochemistry. The laboratory tasks are not structured around a research question but are more like recipes to give the students a map to go by, a base on which to stand. So I want them to learn to draw conclusions from the tests and even be able to go home and do it themselves. […] An advantage of having laboratory tasks with this recipe-like structure with a list of items A, B, C, D is that even the somewhat weaker students can follow along. Even a student who has difficulties with chemistry can then perform a laboratory task. A correctly performed laboratory task actually teaches the student quite a lot.

Christian's lessons are almost always centred on the students performing short laboratory tasks in the form of recipes that never extend beyond one class period. The focus in this example is to teach the students about starch, sugars and their reaction with the enzyme amylase, i.e. on science subject matter. This is an example of *Expository Instruction*. At the same time, students are learning to perform a certain test and Christian also talks about wanting them to be able to conduct tests on their own. However, when asked about learning to do inquiry and learning about inquiry, there was nothing to suggest that these were explicit teaching aims in this example or in his instruction in general. Also, as it shall be noted further on, Christian expressed a rather negative attitude toward IOA.

The next example, provided by Johan, was raised in connection with the problem of motivating students to engage in laboratory activities.

> *Johan:* We have many discussions about the natural scientific way of investigating; that it is important to be meticulous when doing lab work, and to do it thoroughly and carefully. We have, for example, done a laboratory task [in grade 7] in which you mix 50 ml of water with 50 ml

> of methanol and discover that you don't get 100ml. This leads to a lot of discussions and why they have to learn to do lab work carefully. It can take several class periods to sort out, and it has led to us mixing sand and peas because that really makes it obvious that you don't get the same volume. Then you get in to this scientific stuff, and that you have to do more tests.

Here, the students are expected to realise that it is important to do laboratory work carefully. Johan refers to two required characteristics for an investigation to be considered scientific: that it is done meticulously and that the same test is performed several times. Although there are traces here of learning to do inquiry and learning about inquiry, the main teaching goal with this activity is to learn about the relative size of molecules. The students are led to a "discovery" which at first appears to be contrary to common sense. Thus, this is an example of *Discovery Instruction*.

Ann-Catherin initially also provided an example in which students were led to make a "discovery" of the phenomena of heat expansion of water. Upon continuous probing for inquiry-related topics, she recalled the following example.

> *Ann-Catherin:* Last fall, we worked in a more focused manner [in grade 7] with the natural scientific way of working in connection with studying environmental issues. Then we brought up things like the fact that you only vary one thing at a time, because otherwise you don't know what you measure. We did this with secret boxes and an exercise in which you are supposed to find out what is inside a lump of clay. Then its like, that what is in the box is what the majority agrees upon because that is how it is done when you do research. So we calculate the percentage. Then the students protest and say that it is not a math class. But then I explain that this is the sort of thing you use math for. Eventually, someone usually becomes so frustrated by not knowing that they open the box.

In this case, the question, "What is in the secret box?", is given and the students are also taught a method, i.e. controlling variables, in order to investigate and attempt to answer the question. This can be thought of as an example of *Guided Inquiry Instruction*. However, it is not really genuine, given that there is a single correct answer that the teacher knows and keeps from the students. This was one of two examples of the entire 18 with an explicit aim to teach about inquiry and practice doing inquiry in a rudimentary sense. Ann-Catherin explained that she used the Secret Box exercise as a model example to refer back to when discussing other instances of laboratory work with her students.

Another teacher, Lina, also described an example that can be labelled *Guided Inquiry Instruction*. In this case, the students (grade 9) collected samples of snow from different locations around the school and measured the water's pH level. The question and method were provided by the teacher (although the students had some choice where to collect samples). However, as neither the students nor the teacher knew exactly what they would find it is more genuine than the example by Ann-Catherin. Also here the focus is on teaching science through inquiry, i.e. knowledge outcome of type C. Lina also described the following example:

> *Lina:* Today, we began with a task [in grade 7] in which the students are going to study worms and they got to run out and dig for worms. They were really excited. The purpose is for them to find out about the anatomy of earthworms. They are also to do an experiment and investigate if the worms prefer light or darkness. The idea is for them to think about the best way to do that, how you can organise it. They work in groups of three, but each one then writes their own laboratory report. I want them to be able to do a little bit as they please here, which is ok because there are no dangerous things involved as is sometimes the case in chemistry. Hopefully, they will learn that worms are attracted to darkness and moisture. The goal with this particular exercise was not to learn how to conduct an experiment, but rather for them to feel a little freer and realise that you can do it in many different ways.

This example resembles some of the exemplars of inquiry teaching found in the science education literature (National Research Council (U.S.), 2000). Lina has introduced a topic and given the students the task of investigating a specific question. However, when asked about the role of a research question in this and other instances of IOA, she does not appear to have reflected about this. The targeted knowledge is focused on learning about worms and the classification of animals, not about inquiry or learning to do inquiry. Therefore, this is also an example of learning science subject matter (C) through inquiry as a pedagogical method used to inspire. However, as an instructional approach, it can be labelled *Inquiry Instruction,* in line with our taxonomy.

The only example that could be called *Open Inquiry Instruction* was described by Peter. Although he had initially brought another example, he subsequently recalled this one as the interview progressed.

> *Peter:* One example of the students conducting their own investigations is what we are doing right now when the year-nine students investigate different brands of kitchen paper and toilet paper. So the question is; "Which paper do you think is the best?" They are to investigate the papers based on what they come up with and want to find out, asking their own questions. Some groups only investigate the suction ability and feel that that is enough, whereas others begin to think about durability, resistance to pull, appearance and design. They consider many different aspects. Then they get to devise their own method to attempt to answer the question. The degree of freedom is high. They get to plan, structure and perform the actual investigation on their own, and then analyse the results. We take about one class period for the planning and one period for carrying out the investigation, then they get to write a laboratory report as homework. The students think it is a lot of fun. The purpose of this exercise is, among other things, for them to learn to investigate, and the natural scientific way. That they actually learn to be curious and investigate something. It can, for example, involve looking at extreme relationships. Then it is also about learning to describe what happens based on existing models and concepts. Doing your own investigations is also about learning to think critically.

Peter's example is the finale of a unit on the properties of matter. It is the second of two examples with explicit aims in terms of learning about inquiry, although it is rather vague in this case. The investigation is centred on a general question or theme, and the students develop their own research questions and also design, plan and carry out investigations in groups. It resembles Ann-Catherin's example with the Secret Box, in that it appears to have a rather weak connection to any science content, but this was not probed sufficiently during the interview to know for certain. Peter explicitly states that the aim is for the students to learn to investigate in a scientific way. However, it was not clear if they had received any training or instruction in how to formulate researchable questions or design corresponding investigations.

Alfred provided an example different from the others in that it is an umbrella project involving various different activities.

> *Alfred:* One example, which I usually work with in year 7, of how you can capture the students' own questions and help tie the different parts of science into a whole, is called the Long Journey. The idea is for students to work in groups equipping a spaceship for a fantastic journey that will last 2000 years. You are only allowed to use known technology, so it's not some kind of science fiction, and energy is not a problem either because they have solar energy. And they can never be more than 500 people on board and not have any contact with the Earth either. This will then lead to that you start thinking about the circulation of matter. And also questions like where does all the mass in a tree come from and how can a small seed become a large pine tree 50 years later? We work with this for approximately six or seven weeks, but not during every class period. In parallel, the science teaching is about air and water.

The project is done in cooperation with a social science teacher who treats topics such as justice and government. Some of the sub-activities are what Alfred calls “traditional laboratory tasks,” and mentions an example of boiling and condensing water to study phase transitions. There is nothing to suggest that he has learning to do and learning about inquiry as explicit aims with any of the subtasks or the overarching project. This is an example of *Problem-Based Instruction* with the intended learning outcomes in terms of science subject matter (C).

These six examples seem to be quite typical for the tradition of science education in today’s Swedish schools, as colleagues in teacher education, educational research and other teachers have confirmed when presented with them. Although the instructional approaches are varied, the knowledge aims are generally similar in that they focus on science subject matter. Ann-Catherin and Peter’s examples were the only two out of all 18 that did not follow this trend. In these examples, the teachers had explicit learning goals that can be considered learning to do inquiry (A) and learning about inquiry (B).

All of the examples discussed during the interviews were classified according to the taxonomy (Table 2). The distinction between *Expository* and *Discovery* examples is difficult to assess and is based on how the teachers described these as a part of the teaching context. Out of the 18 examples, only four extended beyond one class period, such as the example with the toilet paper, which lasted for three classroom periods. It is particularly interesting to note that the notion of a research question was not a central or organising principle in any of the examples. This topic was explicitly addressed in all but two of the interviews, but none of the teachers said anything to suggest that this was an important concept in their teaching.

Table 2. Classification of all 18 examples

Type of instructional approach	Examples described	Number of examples, N=18
Expository	Christian: Showing the presence of starch	4
Discovery	Johan: Mixing alcohol and water	4
Problem-Based	Alfred: Designing a space ship	2
Guided Inquiry	Ann-Catherin: Exploring the secret box	6
Inquiry	Lina: Studying earth worms	1
Open Inquiry	Peter: Testing different toilet paper	1

Teachers’ Own Descriptions of IOA: Pros and Cons

In general, the teachers valued IOA and the closely associated laboratory work for being fun and helping the students to better learn the science subject matter.

> *Johan:* I have discovered that the students learn a lot more when they work more laboratorially […] I believe that you use both cerebral hemispheres more if you do lab work. […] So it should stick better then. Also it’s, of course, more fun to do lab work.

> *Lina:* When we studied electricity, they also had freer rein to connect [cables] any way they wanted, which they really thought was a lot of fun.

IOA was associated with a high degree of freedom, which was also something positive, as Lina suggests. Another aspect related to learning the subject matter is that instances of more open laboratory work are thought to stimulate the students to think more independently.

> *Ingrid:* In chemistry the laboratory tasks are quite structured, but in physics we have binders with more open laboratory tasks to let the students think more by themselves.

> *Alfred:* The best thing is, of course, when they come up and ask "can't we please check if it works like this?" on their own initiative. […] But that's like one of those ideal moments when you love being a teacher, that wow, now they have come up with an idea that they can actually test.

Alfred expresses an ideal in which students take the initiative to perform their own investigation out of curiosity. However, he also concludes that this is unusual, especially if it's also something that they can actually carry out. There is a suggestion here that all the teacher can do is wait and hope for the spontaneous curiosity of the students to awaken.

It was also expressed that IOA could be particularly well suited to students who experienced difficulties keeping up with the schoolwork in general.

> *Ann-Catherin*: An advantage with the less controlled experiments, I believe, is that the students who are somewhat tired of school would think it was more fun.

However, IOA was also problematic in many ways. Problems that the teachers raised included the students' lack of subject knowledge, the wide range in interests and levels of ambition, the students' worries and frustrations about conducting their own investigations, safety in that IOA was associated with spontaneous investigations, and general limitations in the schools' organisation. There were few suggestions that IOA was problematic because the teachers felt insecure about the meaning or nature of IOA.

> *Christian:* The fact that scientific investigations begin with a question, and so on, we don't talk about that much because they don't know what questions to ask. You must have something in your luggage before you start asking questions.

> *Johan:* When I was new as a teacher, I tried to have somewhat freer laboratory tasks, but I have discovered that you actually have to direct them as to what they should be looking for… The range is really wide in each class. […] It is a difficult act of balancing what level to choose.

An interesting discovery was what we came to call the students' "fear of observation" and "fear of hypothesis". This was expressed by Ann-Catherin, and somewhat more indirectly by Sonja. It refers to the students feeling uncomfortable imitating a research situation in which one aims to generate new knowledge, when the focus in school is simultaneously on learning a predetermined subject matter.

> *Ann-Catherin:* They are quite afraid of formulating a hypothesis or making a guess, which later proves to be wrong. Even though I […] point out all the time that it's important that they have thought about it and believe something about what result they could get before they get started, and that it doesn't matter if it doesn't turn out the way they initially expected.

> *Sonja:* If all that you are after is having laboratory tasks with degrees of freedom, I feel that it can give birth to a certain frustration.

The fear or insecurity many students seem to have in terms of formulating hypotheses and making their own observations may be connected with the fact that IOA is associated with discovery instruction. The students are encouraged to formulate hypotheses (as guesses what they believe will happen) while there simultaneously exists a right conclusion (Andrée, 2007) that they are expected to arrive at or "discover". As the students know through the didactical contract (Brousseau, 1997) what type of knowledge is rewarded i.e. knowing and understanding the right conclusion, this artificial situation leads to conflict and stress.

Safety, particularly in chemistry, was emphasised as problematic in connection with IOA due to its association with spontaneity and freedom.

> *Christian:* Often, the laboratory tasks become a little bit more like recipes, so that as a teacher, I should be able to be more certain that nothing goes wrong. That's why it's difficult with this investigative way of working and being spontaneous. You could do that more often before when the rules were not as strict. Now, even though a question may be raised spontaneously during a class period, you can't do a related laboratory task until you have made a risk assessment of it. On the other hand, you might be able to do it during the following class period, but by then the interest of the students has faded. You need to do it when it is current.

Christian was sceptical of IOA, and as we noted his teaching focused almost exclusively on traditional structured laboratory tasks. Ann-Catherin had similar concerns when it came to IOA. However, instead of scepticism, she expressed a certain amount of self-reproach for not being able to quite live up to the ideal that IOA seemed to represent for her.

> *Ann-Catherin:* All of this with an investigative way of working sounds very fancy, but it is not always that easy. For example, when you bring in dangerous items or talk about such concepts as an atom, which I can't even actually show them. To be really satisfied with an investigative way of working demands a lot of time, so that I constantly have been able to think in advance about where it will lead. Otherwise, it's very easy that I kill their interest at the next question. It is difficult for the students to ask their own questions when they are not familiar with a topic […] I would really like to get away from the structured experiments more, but it's difficult […] I am probably bad at having a high degree of freedom except for the times when the students do an in-depth project.

In the quote above, the safety aspect and the problem that students are expected to start with their own questions are also reiterated. Furthermore, Ann-Catherin brings up the level of abstraction as a difficulty when she questions the possibilities of working with IOA on a topic such as the atom. This suggests that she associates IOA with hands-on activities.

On a more general level, limitations in the organisation of the school in terms of time, classrooms and materials were mentioned as problematic with IOA.

> *Catherine:* When we investigate things in class, new questions pop up all of the time, but it is difficult to get a good flow when the school is organized in such a strange way. Sometimes you would like to be able to do lab work for an entire afternoon and perhaps not just every four weeks when we have the time. In addition, you do not always have the same classroom, so you always have to put everything away afterward, which is another limitation.

In summary, it seems as if the problems that teachers associated with IOA are connected with the image of IOA as very free and based on the spontaneous curiosity and momentary impulses of the students.

Teachers' Own Descriptions of IOA: Contrasts to Inquiry

The teachers described different forms of teaching related to IOA as a contrast between those that are associated with IOA and those that are not. This dichotomy appeared relatively uncomplicated, and the diverse and rich tradition of different teaching approaches that exist in schools does not seem to be accompanied by a specific professional language to talk about them. IOA was primarily associated with instances of laboratory work and hands-on activities. These were contrasted with "traditional teaching" or "didactical pedagogy". Two teachers expressed this by the following:

> *Peter:* I mix didactical pedagogy with letting the students do their own investigations […] The degree of freedom is high.

> *Alfred:* We also do some traditional laboratory tasks and traditional teaching that they can hopefully connect to this Long Journey.

The different expression that teachers used to describe forms of teaching was compiled into two categories (Table 3). There is reason to believe that this limited resolution in the ways of talking about different teaching approaches is also connected to the problems that teachers associated with IOA. The taxonomy presented here could be a useful tool for teachers to talk and think about different teaching approaches in relation to the multiple and complex aims and purposes of education.

Table 3. Expressions used by teachers to describe what is and what is not IOA

IOA	Not IOA
Do lab work	Teach in the usual way
Open tasks	Traditional teaching
Less structured experiments	Didactical pedagogy
Open laboratory tasks	Traditional laboratory tasks
Large degree of freedom	Structured laboratory tasks
High degree of freedom	Recipe laboratory tasks
Laboratory tasks with degrees of freedom	Predetermined laboratory tasks
Independent investigations	Structured experiments
Students get to discover on their own	Filling students with facts
Problem-based	Reading, writing, calculating
Hypothesis-laboratory-task	

Discussion

In this study, we set out to explore what secondary science teachers describe as their own examples of inquiry-oriented teaching approaches. The examples that teachers brought to the interviews and that were brought up during them can be considered a "core sample" (Cobern & Loving, 2000, p. 4) of an existing tradition of practical work in science education in Sweden today. Examples ranged from expository cookbook style laboratory tasks to open inquiry in which students formulate questions and design investigations. As instructional approaches, most examples shared some element of "hands-on" activities as well as a focus on teaching students science subject matter. However, some examples did not have a clear connection to "hands-on" activities, thus indicating that teachers may not always equate inquiry with "hands-on", and that the conceptual borders of teaching approaches are fuzzy. Examples of instructional activities of all degrees of freedom were found, although lower degrees of freedom dominated. It was unusual for teaching activities to stretch beyond one class period, and only four out of eighteen examples were allocated more time. The diversity of the existing tradition of instructional activities does not seem to be accompanied by a correspondingly diverse language for teachers to talk about and describe the different approaches they use.

Practical work in general and IOA were valued by teachers for reasons such as it being fun and for promoting learning and remembering content. These positive aspects related to the perceived pedagogical value of hands-on activities and the fact that IOA was associated with a high degree of freedom in students' work. In addition, this freedom was valued for promoting students' independent thinking skills. However, as we focused more closely on aspects particularly related to inquiry during the interviews, some teachers expressed doubts and problems. For them, IOA seemed to represent a lofty ideal, sometimes worth striving for, but difficult or unrealistic to attain. The basic conflict that the teachers seemed to express or hint at in different ways was the problem of using a method of teaching characterised by them as free, open and spontaneous, to teach young learners a fixed set of scientific theories, laws and facts. In other words, the problematic nature of IOA seems to be found in the friction between what teachers associated with IOA and the constraints they perceived on their teaching situation.

IOA was associated with hands-on activities, discovery instruction, freedom, students' independence and spontaneity. The constraints were the subject content matter as the dominant knowledge goal, the students' diverse background knowledge, interests and abilities of the students and the general constraints of the school, such as time, classrooms and materials. Combined in different ways, the conceptualisation of IOA and the constraints led to the problems of safety, frustration and uncertainty of reaching the intended knowledge goals. Given that IOA was associated with hands-on activities and using students' spontaneous interests and questions to guide investigations, safety was considered an issue, especially in chemistry. This seems to be connected with a view of hands-on activities as rather fast and short in duration. In addition, because IOA was associated with discovery learning, freedom, students' independent work and the emphasis on learning science subject matter (C), the result could be different forms of frustration in the classroom. In particular, we noted the comments about students' fear or uneasiness when it came to formulating hypotheses and drawing conclusions based on their own observations. This was further complicated due to the fact that all of the teachers used the notion of a "hypothesis" as the equivalent of a prediction or guess, rather than a tentative explanation, reducing the act of formulating a hypothesis to guessing the correct conclusion. This issue was explored in more depth in another article based on the same study (Gyllenpalm, Wickman, & Holmgren, 2009).

With this study, we also wanted to compare how the teachers' own examples related to conceptualisations of inquiry in the science education literature. Inquiry has been conceptualised in science education both as an instructional approach and a learning outcome. We chose to focus on two learning goals specifically associated with inquiry in the literature: learning to do inquiry and learning about inquiry (Bybee, 2000). These knowledge goals that were specifically associated with inquiry were found to be almost completely absent in the teachers' descriptions of their own teaching, in line with what other researchers have found (Högström, 2009; Högström et al., 2005; Lederman, 1999; Windschitl, 2004). Some of the examples exhibited features of inquiry as a teaching method in that they attempted to mimic authentic scientific research (e.g. investigating toilet paper). However, the central notion of structuring investigations around a question did not seem to be important in the existing tradition. Thus, it can be concluded that although there are teaching practices in the existing tradition that exhibit elements of inquiry as an instructional approach, they are not matched with learning goals specific to inquiry.

The findings in this study have implications for teachers who want to reflect on the nature of practical work as a part of their teaching as well as for the development and use of curriculum materials based on ideas about inquiry. This study suggests that inquiry-oriented approaches will remain problematic unless learning about scientific inquiry and learning to do inquiry are give more emphasis as explicit knowledge goals. The division between learning science subject matter and learning about inquiry is analytical, and we do not believe that one can learn about inquiry without also acquiring a certain grasp of the subject matter. It is obvious that the process of teaching science is not linear, and the emphasis between subject matter and learning about inquiry will have to shift in a cyclical manner. Although learning about inquiry is not the only objective with science education, we want to highlight the importance of matching the emphasis of distinct knowledge goals with distinct methods of teaching. This involves considering *methods of inquiry* (such as control of variables, formulating researchable questions, formulating hypotheses and using random sampling) as part of the subject matter that students learn as distinct from other more well-known domains of subject matter (such as the laws of mechanics), and to match the learning goals with *methods of teaching* in a reflective way.

If the primary focus is on teaching students science subject matter (C), then the instructional styles in which the answers are given will seem more relevant. In *Expository Instruction* and *Problem-Based Instruction,* the science subject matter is always close in view. The other approaches are problematic from this point of view because it is uncertain whether the students will reach the anticipated conclusions, especially in a given time frame. Given that IOA was associated with discovery instruction, freedom and students working independently, reaching the learning goals in terms of subject matter became problematic. Furthermore, as IOA was also associated with hands-on activities, the subject matter that is considered more theoretical and abstract appears even more problematic. *Inquiry* and *Discovery* instructions may then only be favoured based on the belief that if done well, it will help the students to remember the content better and perhaps make science education more enjoyable. Thus, from the point of view of teaching the correct explanation, these styles of instruction have pedagogical value for the teachers only in a disconnected way from their primary knowledge goals. In fact, research is ambivalent regarding the relative effectiveness of inquiry-oriented teaching approaches to teach science subject matter (Lederman, Lederman, Wickman, & Lager-Nyqvist, 2008). These problems with inquiry instruction may possibly increase as students get older and begin to realise the trade-off between investing time and energy in doing inquiry versus focusing on learning the correct explanation, which is more important in assessments where learning the correct explanations is usually given more emphasis.

Previous research has identified some of the same themes presented in this study, such as the dilemmas teachers express in relation to inquiry (Anderson, 2007), and that inquiry is an ambiguous term in science education (DeBoer, 1991). The fact that practical work with higher degrees of freedom and learning about inquiry as a goal are unusual has also been described (Hult, 2000; Högström, 2009; Högström et al., 2005; Löfdahl, 1987). The new contribution of this paper is that it provides a first-hand description of teachers' own examples of IOA and how they conceptualise inquiry, and that these descriptions are related to the ongoing discussion about inquiry in science education research and policy. We also propose that some of the problems and dilemmas that teachers describe with IOA can be resolved by clearly distinguishing between *methods of teaching* (e.g. the instructional approaches described in Table 1) and *methods of inquiry* (e.g. control of variables), where the latter are a goal of instruction and the former a strategy for instruction. The taxonomy of instructional approaches presented here is also new and can be used to consider what approach would be more useful at certain points in the progression of a teaching unit.

The development and implementation of curriculum materials and curriculum reforms needs to take into account the existing tradition and school culture. Discussions about education are generally more productive if one begins with the intended learning outcomes, the "what-question" and then moves on to the "how-question" of teaching methods. This is especially precarious for the notion of inquiry in science education, as there is a high risk of misunderstanding when talking about *methods of inquiry* as a learning outcome and *methods of teaching* through inquiry as a pedagogical strategy. What this study suggests is that teachers have a strong tradition of practical work that they associate with IOA in various ways. Although the notion of IOA is not problematic for many teachers, working with IOA may be. If teachers choose not to work with IOA, their reasons for doing so may be different from what has been assumed in curriculum reforms, i.e. that teachers need professional development in inquiry teaching. The problems teachers raised in this study concerned aspects such as time, safety and students' interest, rather than a lack of understanding IOA or a lack of materials. The fact that the teachers' examples in some ways resembled inquiry, as conceptualised in the science education literature, but also lacked essential elements, and the ambiguities in terminology to describe instructional approaches are issues that needs to be addressed. Otherwise, new curricular materials and reforms may be absorbed into the existing tradition and transformed into more of what already exists.

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Hanne Møller Andersen, PhD, is assistant professor in science education at Aarhus University. Her main research interests are students' motivation and learning in science classrooms and students' science identities. Based on many years of experience in upper secondary school as a chemistry and biology teacher, she also has an interest in the development of science teaching e.g. teacher training and intervention studies.

Lars Brian Krogh, PhD, is assistant professor at Aarhus University and has a history as a teacher of physics and chemistry in upper secondary school. Among his research interests are studies of students' engagement with science from cultural and psychological perspectives ("border crossing" and "science identities") as well as studies of how professional development can enhance science teachers' capabilities to facilitate students' interest and act as cultural brokers.

HANNE MØLLER ANDERSEN
Centre for Science Education, Aarhus University, Denmark
hanne.moeller.andersen@cse.au.dk

LARS BRIAN KROGH
Centre for Science Education, Aarhus University, Denmark
lars.krogh@cse.au.dk

Science and mathematics teachers' core teaching conceptions and their implications for engaging in cross-curricular innovations

Abstract

Previous studies have found core teaching conceptions (CTCs) to influence teachers' actions, i.e. how they engage with new teaching practices (e.g. Lotter, Harwood, & Bonner, 2007). This study explores typical CTCs and their subject specific nature in a sample of teachers from physics, biology, and mathematics in Danish upper secondary school. Teachers' CTCs were investigated through their essay-responses to a set of open core questions, administered through a web-platform. Results demonstrate that teachers' CTCs come in subject specific flavours, encompassing their purpose for teaching the subject, their conceptions of teaching and learning, and their conceptions of interdisciplinary teaching. It is argued that such differences shape teachers' engagement with new cross-curricular innovations in the Danish context. Assessing and addressing typical and personal CTCs are found to be crucial to a successful implementation of current reform-initiatives, for teacher training, and for self-regulated professional development among teachers.

Introduction

Teachers hold a variety of conceptions about themselves, about the world and about their professional place in the world. In particular they have conceptions about what constitutes teaching and learning in their own subject areas. These conceptions are shaped by various influences which include: personal experiences as students in the school system; enculturation into a specific discipline at university; approaches taken during teacher training programmes. Through such influences one intuitively would expect teachers' conceptions to be different for teachers coming from different subject backgrounds. The explorative study reported in this paper is a first attempt to identify the nature of these differences within the sciences, focusing on physics and biology, and between these sciences and mathematics, and other disciplines.

We believe that an explicit awareness of the more fundamental teachers' conceptions is important since research (e.g. Lotter, Harwood, & Bonner, 2007; Tsai, 2007) has documented that they shape the way teachers teach, how they implement new reform-initiatives, and their participation in professional development activities. Generally speaking, curricular intentions (and reforms) are at risk whenever teachers' views are discordant with the underlying rationale of an innovation. Here, we subscribe to the view expressed by Mellado:

> "The study of science teachers' beliefs or conceptions thus takes on special importance as a first step toward generating in the teachers themselves conceptions and practices better suited to the currently proposed curricular objectives." (Mellado, 1998 p.198).

The kind of teacher conceptions which we have in mind might be revealed through reflective questions such as: What defines my subject and how is it changing? What is the contribution of my subject to the schooling of students? How does it relate to the contributions from other subjects? Such conceptions are clearly a fundamental part of a teacher's professional identity, and we would argue that the capacity to develop one's own professional identity and to expand one's teaching approaches is linked to an explicit awareness of those conceptions.

In this paper the discussion of teachers' fundamental conceptions is framed by the recent introduction of new types of cross curricular innovations in the Nordic countries and elsewhere. For example, the 2005-reform of Danish Upper Secondary School (Gymnasium-stx) entails two new subjects (NV: NaturVidenskabeligt grundforløb ("Basic Science") and AT: Almen Studieforberedelse ("General Preparation for (Tertiary) Studies"). Both subjects involve science(s) in different ways, they are interdisciplinary by nature and they demand a thematic and collaborative pedagogy. In NV the collaboration is within science subjects, introducing students to *common scientific methods and reasoning* with an emphasis on *how to do science*. AT is even more demanding in its inclusion of knowledge from different faculties; aiming at students' ability to *compare and discuss related epistemologies at a meta-level.* Especially AT calls for new kinds of teacher knowledge and practice. First of all teachers need to have more articulated views on the nature of science(s) (especially epistemology) and know more about other school subjects. But it is not only a matter of knowledge. These courses also challenge more traditional teaching conceptions with their new emphases on process- and metacognitive learning objectives and their insistence on inter-disciplinarity and teacher collaboration. Similar considerations are actualized in relation to the new programme *Teknologi og Forskningslære* introduced in Norway from 2007.

Important questions arising from such developments are whether teachers from different school sciences are equipped to contribute in a constructive manner. And if not, how can existing teacher training and development programmes be adjusted, utilizing and addressing teachers' conceptions?

Perspectives on teacher conceptions

Studies of teachers' conceptions about science and science teaching have developed into a major research program which is documented in the bibliography on *Students' and Teachers' Conceptions and Science Education* (Duit, (2007)), and in the recent review of research on science teacher knowledge (Abell, 2007). Particularly, the review is built around the notion Pedagogical Content Knowledge (PCK, Shulman, 1986), which have been extended with a belief component *Orientations towards teaching* (Magnusson, Krajcik, & Borko, 1999) that encompasses (an amalgamate of) many of the teacher conceptions addressed in this paper.

Such fundamental and personalized conceptions are found to guide teachers' decisions and actions in the classroom: *"Teacher beliefs often act as "filters" through which information about students, learning and instructional strategies flow"* (Lotter, Harwood, & Bonner, 2007 p.1319). A number of studies have shown a strong relationship between core domains of teachers' conceptions and their classroom practice (e.g. Dillon, Obrien, Moje, & Stewart, 1994; Appleton & Asoko, 1996), while others have found a more moderate relation (e.g. Abell & Roth, 1995; Meyer, Tabachnick, Hewson, Lemberger, & Park, 1999).

Core Teaching Conceptions

Lotter et al (Lotter, Harwood, & Bonner, 2007) have coined the term *Core Teaching Conceptions* (CTCs) to describe central beliefs influencing teachers' implementation of new inquiry based practices. Their CTC's belong to one of the following domains: views of science, purpose of education, students, effective teaching. These domains were suggested by literature studies, and the specific conceptions "emerged during the qualitative analysis of the interview and observation data" (ibid. p.1328) from a study of three teachers. The CTC's are considered "relatively stable" (ibid. p.1341) but they can interact in different ways dependent on the context. The limitation of this study clearly is its minimal sample size, which makes the resulting model exploratory and leaves the question of completeness open.

Research on the subject-specificity of teachers' conceptions

Considering the extent of research studies on teacher conceptions it is noteworthy that relatively few have investigated their subject-specificity. Säljo (Säljö, 1979) expresses reservations regarding the existence of more or less universalist conceptions of learning and argues that different educational environments might be expected to define learning according to *"different socially and culturally established conventions with respect to what counts as learning"* (p. 104). An obvious implication of this would be that teachers' conceptions of learning should differ from subject to subject. With this point in mind a number of phenomenographic studies (Langer & Applebee, 1988; Marton & Booth, 1997) set out to study differences of conceptions of learning across contexts and samples. Some authors (e.g. Pillay, 2002) emphasize the similarity of conceptions of learning found. However, the very general level of categorization of such learning conceptions tends to obscure contextual differences. Furthermore these studies identify qualitatively different categories of conceptions, not differences in frequency of specific categories. Much more context is found in Donnelly's (Donnelly, 1999) comparison of science and history teachers' educational aims/purposes. History teachers were found to have a relatively uniform set of aims while "the scientists ranged more widely" (ibid. p. 23). This conclusion may well be the result of pooling teachers from a range of distinct science subjects into a single "science" group. All in all, it seems that this research paradigm has shed only a narrow cone of light onto the subject-specific nature of teacher conceptions.

We have found no research studies looking for differences in teacher conceptions between science subjects apart from an unpublished theses by Krogh, where he uses an eight-dimensional framework TESSA ("The Ethos of School Science Analysis") for an investigation of conceptions held by pre-service teachers in physics and biology (Krogh, 2006). Even though sample sizes were moderate (physics: 28, biology: 18) several significant differences ($p<0.05$) emerged. Thus, biology teachers were found to be much more oriented towards life-world authenticity, inclusion of affective aspects and social organisation of learning than physics teachers.

Research on the impact of CTCs on teachers' implementation of new curricula and participation in (cross curricular) innovation

A central issue for the present paper is that the filtering function of teachers' core teaching conceptions constitutes a critical element in the transformation of curricular intentions to an implemented and attained curriculum, often leading to gaps between these in curricular reform. Roberts, in his famous paper *"What counts as science education"* describes how *"teacher interpretation and (value laden) teacher loyalties"* (Roberts, 1988 p.28) shape science education, implying that curriculum implementation (and reforms) will falter unless there is congruence between views/ conceptions held by teachers and a new curriculum. This has resonances with Lotter, Harwood & Bonner (2007), who studied teachers' use of new inquiry based methods throughout a professional development programme: "*to be successful inquiry professional development must not only teach inquiry knowledge, but it must also assess and address teachers' core teaching conceptions*."

We have argued that there is a lack of research on differences between core teaching conceptions held by teachers from different sciences, and we hypothesize that some of these are likely to influence the way teachers engage in cross-curricular teaching and in implementation of curricular reform. To explore these issues this study addresses the following two questions:

1. *What are the similarities and differences in the CTCs for a sample of physics, biology and mathematics teachers?*
2. *What are the implications of these similarities and differences for teacher engagement in cross curricular reform in particular and in professional development activities in general?*

Methodology

This study was carried out in the context of a university-based in-service workshop, with the aim of preparing teachers for the new interdisciplinary course AT in upper secondary school. Most teachers had volunteered to attend the course, but some were selected by their principals. The teachers had subject backgrounds from all across the curriculum.

As a pre-reflective part of the course work, the teacher participants were asked to respond in writing to a series of web-based questions about their academic discipline and teaching and learning of the related school subject. 180 teachers from a possible total of 305 participants produced sustained pieces of writing and this became the overall sample for the study. In this respect the sample might be biased towards the more enthusiastic and progressive end of the Danish teacher group. The analysis presented in this paper is based on responses from teachers of physics (17), biology (10), and mathematics (14) with teachers in social sciences (15) and Danish language (12) being drawn upon as reference groups representing the two non-science faculties within AT.

Web-based questions

The web-based questions were made accessible to teachers through individual codes. In addition to a number of background questions (gender, place of employment (school), age, teaching experience (number of years), teaching subject etc) six open-ended 'core questions' about teachers' conceptions of their discipline and teaching of the subject were posed. Each core question had its own rubric for answering. The number and content of these core questions were determined after extensive literature studies, and though they map a larger domain than the four domains of Lotter et al we do not claim that they are a complete list. As an inspiration for teachers and to indicate the possible breadth of the core questions each was supplemented with a number of sub-questions. The phrasing of the questions reflects the meta-reflective stance to knowledge integral to the AT-context:

1. **Conceptions of the (academic) discipline?** What characterizes it as a particular field of study? Is it a distinct way of knowing? Do researchers apply a special kind of work process or procedures to gain knowledge? Other relevant comments?
2. **Relationship between academic discipline and school subject.** Do your see the school subject as a reduced, but fairly loyal version of the academic discipline? If it is an adaptation: what kind of adaptation has taken place? Do you see these adaptations as meaningful? Other important aspects?

3. **Purposes of teaching the subject in school.** What reasons do you see for teaching the subject? Is it legitimized by providing particular skills, competences or a broader scientific literacy? Can its place in the curriculum be substantiated by democratic, cultural literacy, utilitarian (personal or societal) arguments? Or…?
4. **Your subject versus other subjects taught in upper secondary school.** In what ways does the subject you teach differ from other school subjects? In which ways can your subject interact and collaborate with other subjects in Upper Secondary School? Other considerations?
5. **Learning the subject in school.** What are the indications of students' learning in your subject? Is there any best way to learn the subject? What do you consider as major barriers to learning the subject?
6. **Teacher role and identity.** What teacher role is best suited for teaching your subject? How would you describe your relation to the discipline and subject teaching? ("It's just a professional affair"; "It's an important part of my life"; "It's an integrated part of my identity"). What kind of personal opportunities/limitations do you see in relation to teaching the subject?

Analysis of teacher responses

First, we noticed that teachers actually responded as if they had used the load of sub-questions for inspiration. Instead of answering all aspects teachers tended to "get the idea" from the first aspects and continued with related aspects they found salient.

Our first essay analysis had the individual teacher as unit, and the individual set of six core question responses were studied hermeneutically. Thus, the response to one question was allowed to support the interpretation of another. Only after all intra-case-analysis was concluded we turned to inter-case analysis for similarities and distinctions between teachers from the span of subjects. The composite teacher essays were approached with interpretive lenses afforded by a range of theoretical and empirical studies (see tables below). From these a number of tentative categories and meanings were derived from the outset, and through a process of constant comparison with the intra-case essays their usefulness and completeness were evaluated and validated. The two researchers independently categorized all essays, and subsequently met to negotiate meanings/interpretations and compare categorizations for each teacher, in order to ensure reliability. Generally, the interrater agreement was considerable from the very beginning, e.g. Cohen's Kappa > 0.7. However, in the worst case of mathematics Cohen's Kappa initially was 0.55 for some of the very first and premature coding. All codes and meanings were iterated until complete agreement was reached. In a few cases major changes of initial categories occurred (e.g. completely new categories had to be invented), more often meanings were adjusted. When teachers' responses included views covered by more than one category, all categories were registered. The identified categories are outlined below. However, notice that only five of the core questions are documented, since the last question on *Teacher role and identity* evoked little elaborate writing. We shall only be dropping a few comments from this domain. Furthermore, core questions 1 and 2 are analyzed together, as many teachers have problems to distinguish academic discipline and school subject.

Purposes for teaching the subject in school

In developing categories for teachers' views on the purposes for teaching their subject we drew on theoretical work (Driver, Leach, Millar, & Scott, 1996) and (Sjøberg, 2005), where the following purposes were identified: economic, utility, democratic and cultural. However, since these purposes all refer to science for all, they do not include more discipline-oriented purposes. Here Roberts' classic work on curriculum emphases (Roberts, 1988) provides a relevant extension of the field. Roberts describes 7 types of *curriculum emphases* that are embodied in objectives of science learning. Among these there are several discipline-oriented purposes, e.g. *Correct Explanations, Scientific Skill Development,* and *Solid Foundation.* Analyzing our data with these codes, we

Table 1. Description and indicators of categories used in the analysis of teachers' conceptions of the purpose of teaching their subject.

Purpose	Description	Some Indicators
Everyday coping (Sjøberg)	Personal utility in everyday life	Useful knowledge about human body, health, technology (energy, IT), money-transactions (bank, trade), literacy....
Solid foundation/ Scientific Skill Development (Roberts)	Basic knowledge, solid foundation for further study, scientific skills	Knowledge and methods necessary for further education or as a tool for other subjects (e.g. physics/chemistry, economy/social science, technology, medicine and ICT).
Societal prosperity (Sjøberg)	Societal wealth and development	Science as vehicle for wealth (e.g. high standards of living, source of revenue...). Science and S&T candidates necessary for development and economic growth.
Civic literacy (Sjøberg)	Knowledge about socio- scientific issues. Democratic influences and citizenship.	Capacity to understand, discuss, and critically evaluate Socio-Scientific Issues (e.g. climate, gene-technology, energy-production, limitations of societal models...), including media-representations. Engage students in societal discussions and decision-making.
"Bildung"	Knowledge leading to a personal enrichment and development.	"Habits of mind" (Dewey) (wonder, logical thinking, critical reflexivity), autonomy & identity, understanding our place (in time/space, history & culture), and science as culture. Not oriented towards specific instrumental purposes.

found no instances of *Correct Explanations,* and in most cases characteristics of Scientific Skill Development and Solid Foundation were inseparable. Table 1 presents the final categories for analyzing teachers' conceptions of purposes for teaching their subject.

Conceptions of teaching/learning

Several researchers have found that teachers' conception of good teaching is strongly related to their ideas about how students learn (Boulton-Lewis, Smith, McCrindle, Burnett, & Campbell, 2001; Koballa, Graber, Coleman, & Kemp, 2000), so in our description and analysis we have chosen to group the two together. Our evaluation of teachers' conceptions of teaching and learning are based on their responses to core questions 4-6. Our analysis is inspired by (Tsai, 2002), who has identified *Traditionalist, Process,* and *Constructivist* teacher positions in relation to teaching and learning. However, since consistent *Constructivists* were rare in our sample we invented supplementary categories to help us differentiate aspects of the other positions, e.g. explicate *Student Centred* and *Subject Centred* aspects. We found it relevant to indicate whether students' abilities/interests or subject structure/curriculum demands were central in the remarks about content. Similarly, we indicated whether students or teacher were given major *agency* in the teachers' descriptions of pedagogy. Finally, we registered if teachers described deliberate shifts in agency (e.g. handing over agency to students) as their lessons develop. Table 2 presents categories used for an analysis of teachers' conceptions of teaching and learning.

Table 2. Description and indicators of categories used in the analysis of teachers' conceptions of the teaching/learning process.

Teaching/learning	Description	Some indicators
Traditionalist teacher (Tsai)	Emphasis on knowledge as a product to be transferred and acquired by the students	Transferring knowledge, firm answers, clear definitions, presenting truth and facts, giving explanations.
Process oriented teacher (Tsai)	Emphasis on mastery of disciplinary processes and procedures	Scientific methods, problem-solving, Experimental knowledge
Constructivist teacher (Tsai)	Emphasis on knowledge as a personal construction of understanding	Helping students to construct, discussion and cooperative learning, students' alternative conceptions, meta-cognition, critical thinking
What decides content?	Are students' or subject demands emphasized in teachers' talk of content and curriculum as part of the teaching/learning process?	*Subject centred:* e.g. emphasis on curricular demands or subject matter structure... Student centred: e.g. students' abilities, alternative frameworks, experiences, interests...
Who has major agency?	Who is given major agency in teachers' description of teaching/learning processes and pedagogies facilitating learning.	*Teacher Agency:* e.g. lecturing, teaching at the blackboard, students being introduced to...; teacher has to go over content... *Student Agency:* e.g. group work/ being supervised by teacher, students' presenting, doing practicals, asking questions, solving problems
Shifts in agency?	Do teachers mention deliberate shifts in agency as lessons progress?	From teacher to student agency – or vice versa? Other? Flexible?

Conceptions of academic discipline and related school subject

Traditionally most science teachers have focused on students' learning of the products of science (theories, laws and concepts), but lately there has been an increased focus on students' learning about science processes, being a central component in "scientific literacy" oriented curricula (Dillon, 2009). Tsai has in his study of teachers' conceptions of their discipline identified a category of *Traditionalist* having a product oriented view and a category of *Process orientated* having a process oriented view (Tsai, 2002; Sjøberg, 2005). In the present study conceptions of the discipline and/or school subject are merged since teachers' responses showed little awareness of the distinction between the two.

The differentiation between process and product orientation is meaningful for most teachers, but not for teachers of mathematics, because they usually describe their subject in different terms. To catch mathematics teachers' views we draw on Paul Ernest's description of mathematics teachers as being oriented towards 'conceptual understanding', 'problem posing and solving' and 'skills

Table 3. Description and indicators of categories used in the analysis of teachers' conceptions of their academic discipline and/or the distinction between discipline and school subject.

Academic discipline and/or school subject	Description	Some indicators
Product orientation (Tsai; Sjøberg)	Focus on products and established knowledge	*Sciences:* Natural theories & laws. Science as exact/Truth/Facts. Explanations of nature. Universal character of knowledge. Other: Focus on texts, grammar ...
Process orientation (Tsai; Sjøberg)	Focus on the process of how science works and creation of new knowledge	*Sciences:* Scientific method(s). (Controlled) Experiments. Knowledge/hypotheses are tested. Procedures (e.g. replicability)... Other: text-analysis, interpretation, communicative competence...
Skills mastery orientation (Ernest)	Instrumentalism, use of tools and techniques in an educational setting	Mathematic as tool/support for other subjects. Application. Training of skills.
Distinction between academic discipline and school subject	Do teachers see any distinctions between the two?	*Same essence:* True version: No distinction in purpose, nature, or methods. True - but content-reduced. True, but complexity adjusted. *Different in essence:* Differences related to purpose, nature, methods, content

mastery' (Ernest, 1989). Ernest associates the first with a "unified body of certain knowledge" which makes it a product-orientation, while the 'problem posing and solving' is a process-orientation. New, however, is the 'skills mastery-orientation' with its instrumental view. Table 3 presents the categories used.

Conception of interdisciplinary teaching and the role of the subject

Teachers' conceptions of interdisciplinary teaching and the role played by their subject pedagogy (e.g. subjects in sequence, parallel or integration (Hurley, 2001)). In answering the question "In which ways can your subject interact and collaborate with other subjects in Upper Secondary School?" teachers took different perspectives. Some of the teachers focused on the contribution and benefits (application, aims) of their subjects, while others referred to interdisciplinary themes, experiences and aims.

Findings

We present and discuss our results for teachers' CTCs in accordance with the structure of the preceding paragraph: 1) purposes for teaching the subject in school; 2) teachers' conceptions of teaching/learning; 3) teachers' conceptions of the academic discipline and the relationship between school subject and academic discipline; 4) teachers' conceptions of interdisciplinary teaching and ways in which their subject could interact with other subjects.

Table 4. Description and indicators of categories used in the analysis of teachers' conceptions and attitudes towards interdisciplinary teaching.

Interdisciplinary teaching	Description	Some indicators
Inclination towards interdisciplinary teaching	Positive or negative attitude in relation to interdisciplinary teaching	Negative: No mentioning Positive: Mentioning themes/cases suitable for interdisciplinary teaching
Perspective on Interdisciplinary teaching	Internalist subject perspective or integrated perspective	Subject perspective. Mentioning of specific subject matter and skills. Subject enhancing collaboration with subjects from same faculty. Shared teaching of common methods. Integrated perspective. Mentioning of themes and project drawing knowledge from more than one faculty e.g. Cosmology, Self-esteem and plastic surgery, Creationism

1. Purposes for teaching the subject in school

The teachers identified a range of purposes for teaching their individual subjects. The overall analysis reveals that most of the science teachers (some 60 %) stated more than one purpose, while teachers in social science and Danish tended to restrict themselves to a single purpose. Details are shown in the figures below where the teaching purpose-profile for each subject is inserted as a mini-figure, allowing individual scrutiny *and* comparison. In the mini-figure each category of purposes is represented by a corner, and the axes indicate the share of teachers within a given subject that mentions the specific purpose. As can be seen from these figures the science teachers' purpose-profiles come out very differently for biology and physics and these both differ from other subjects.

The profile for physics teachers appears to be relatively homogeneous across different purposes and strikingly they are the only group of science teachers in our sample to display this trend. In this respect our study indicate that the previous study of (Donnelly, 1999) is likely to overlook significant differences. Interestingly, our physics teachers most frequently refer to 'Bildung' as a central purpose, contrasting with biology teachers who refer to civic literacy and students ability to understand and discuss socio-scientific issues. A typical biology teacher writes:

> "Many of the topics that we engage with in biology are discussed in the media on a daily basis, and that's exactly why students should learn to respond to such issues and participate in related debate" (teacher 2)

The mathematics teachers have the usefulness of mathematical skills in relation to other education (Solid foundation) as their main argument. However, often this is combined with a particular formative Bildung-orientation, associating autonomy and enrichment with logical reasoning.

> "Students must learn mathematics, primarily because mathematics has huge applicability within science, economy, social science, technology, medicine and ICT, but also because it is important to learn to analyze and deduce complex problems and get a sense of proportions" (teacher 60).

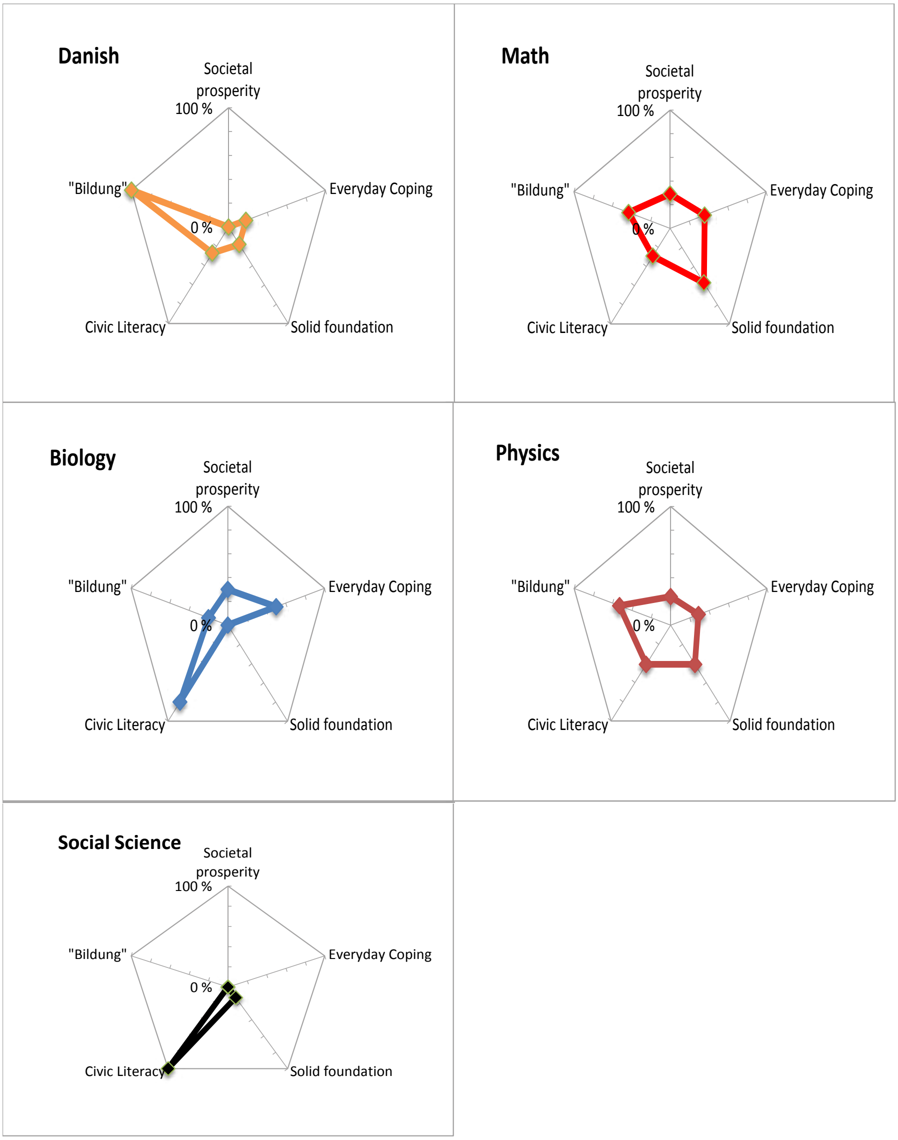

Figure 1 The distinct profiles of Teaching Purposes for teachers from various subjects (upper secondary school).

Characteristically, teachers in Danish and social science downplayed instrumental purposes, like societal prosperity, basic skills or everyday coping. Instead Danish teachers emphasised students' 'Bildung', as illustrated:

> "…it takes awareness of language and communication, and analytical sense across different social contexts to gain a better understanding of the lives of other people, and hopefully also more tolerance and interest. In addition, historical insight into cultural trends is an essential precursor for participation and understanding of contemporary cultural trends and orientations." (teacher 83)

The social science teachers were more focused on students becoming informed citizens and their ability to take active part in decision-making and democracy:

> ”I suppose social science gains a particular democratic value by introducing students to matters of the society and what influences them, thereby contributing to (active) citizenship” (teacher 69).

In this way teachers' conceptions of the purpose of learning their subjects clearly turn out to have subject-specific flavours. In different ways these relate to the rhetoric of the 2005 Danish reform of Upper Secondary school (e.g. Danish Minister of Education at first reading of reform bill, 31 October 2003), where science in general was designated as an equal contributor to 'Bildung' and civic literacy. Thus from our analysis, biology teachers along with the teachers in social science are more likely to be oriented towards students developing civic literacy, while physics teachers tend to be the more 'Bildung'-oriented science teacher group.

2. Conceptions of teaching/learning

Most science and math teachers (app. 60%) emphasised the importance of students taking an active part in teaching and learning activities (e.g. problem solving and practical work), but there is a difference between biology and physics/mathematics teachers. Many of the physics/mathematics teachers (app. 30%) conceptualised the optimal way of teaching as a sequence, initiated by the teacher's explanation of important subject matter, followed by students working on related problems. This *telling-applying* approach is illustrated by a physics teacher's description of the best way to teach and learn physics:

> "[Students] are presented with physics explanations, laws and interesting phenomena that they might already have encountered. This is followed by student-work on similar "cases" where students try to find solutions and explanations. In the end students make a presentation of their work either orally or in written text" (teacher 19)

Biology teachers tended not to envision this kind of standard procedure; instead they mentioned variation as an important element and several biology teachers pointed to the fact there is no best way of teaching biology; the optimal way depends on the given situation and the students present in the classroom (a view shared by some 15% of the sample). One biology teacher wrote about good teaching:

> "…variation, serious consideration of students' questions, an understanding of students' points of departure and serious consideration of the differences among students" (teacher 9)

In contrast to physics/mathematics teachers, biology teachers did not mention teachers lecturing when they wrote about the best way to learn biology and they were less focussed on students' capability to do problem solving, which might be explained by a more widespread use of problem solving in the evaluation of students' abilities in mathematics and physics.

Teachers' conceptions of students typically enter this study through their writing about barriers to teaching/learning. Teachers from all three subjects (a minority) mentioned students' lack of motivation and effort as an important hindrance for learning. The most notable difference is that a few biology and physics teachers (6 teachers in total) mentioned students' alternative frameworks as potential barriers for students learning while mathematics teachers tended to focus on students' lack of ability to handle abstract thinking (6 teachers).

3. Conceptions of discipline

One remarkable finding of this study is that many teachers had great difficulty in distinguishing between the academic discipline and related school subject, which makes it difficult to report on teachers' conceptions of their discipline. About 40% of the teachers responded to the question on characteristics of their academic discipline with reflections clearly referring to their school subject. This appeared to be a general trend, across disciplines, and can be illustrated by the following;

> "Biology is a subject based on experiments. The students learn to combine theory and practice. The practical work is an important part of biology teaching…" (teacher 7)

We have considered the possibility that the apparent mix-up could be a symptom of teachers' misunderstanding our rather academic 'core-question'. Actually, a few teachers do express that this first 'core-question' is hard to understand, and there is a few blanks. However, the share of such responses is far below the share of 'non-distinguishers'. Most importantly, asking to the 'Relationship between academic discipline and school subject' we find additional evidence that the blurring between academic discipline and school subject is not an artifact. Teachers' responses here were analyzed and quantified, with the results shown in Figure 2.

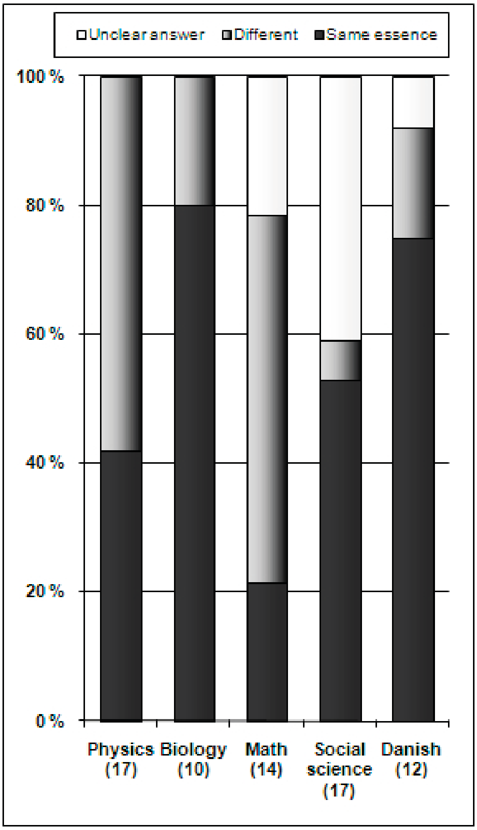

Figure 2. The relation between school subject and academic discipline (numbers of teachers are indicated in parentheses).

Explicitly asked 50% of the teachers maintain that their school subject is *in essence* just like the corresponding academic discipline. Only 1/5 of the total sample of teachers provides substantial arguments for a clear distinction.

The subject related response of *In-essence-the-same* appears clearly from Figure 2. Almost 80% of the teachers in biology considered school science to be essentially the same as academic science, while only 20% of the math teachers found it to be the case. Many biology teachers described school biology as being a fairly close to academic science, as can be seen in the following:

> "School biology is a true version of academic biology. Central to the teaching of biology is the scientific method, which is what aligns it with the academic discipline." (teacher 11)

For this teacher scientific method acts as connector between school biology in upper secondary school and academic biology. In addition the relevance of biological knowledge in relation to social scientific issues - both at academic and school level – appeared as a reason for this blurring. By way of contrast, most mathematics teachers saw school and academic mathematics as essentially different enterprises, a view backed up with reflections on the nature of school mathematics as mainly being focused on practical uses, while academic mathematics is more concerned with developing mathematical proofs and models. The response from a typical mathematics teacher illustrates the point:

> "Mathematics in schools lacks some of the aspects of disciplinary mathematics. E.g.: there is not much proof and deduction left. Mathematics in upper secondary is more like a tool to be applied in other subjects: Pick the right formula, insert some numbers and calculate or let a program do the calculation for you. This situation may be caused by the way written (national) exams are configured. I think, you should be able to find mathematical domains, where calculators are downplayed and proof and logical reasoning are at the core." (teacher 51)

Mathematics teachers frequently referred to limitations in students' capabilities of abstract and logical thinking, when they argued for a distinction between school and academic science.

A high proportion of teachers in Danish language and social science considered the school subject and academic discipline to be in essence the same. These teachers were aware of different levels of subject matter knowledge, but they had a notion of methods and procedures being the same in upper secondary and at university level.

Product-Process emphasis

Characterizing their academic and/or school subjects most teachers mentioned processes, products, or both. Figure 3 shows how process- and product-emphases were realised across subjects.

Teachers' characterizations of their subjects in terms of products and/or process do differ. It is a general trend that the science teachers conceptualised their subjects with a strong emphasis on processes. In contrast to other groups, the mathematics teachers had a strong emphasis on skills mastery, e.g. almost 60% of this group of teachers drew attention to mathematical skills. One of the mathematics teachers characterised his subject in the following way:

"[Mathematics] provide a service and methods to other subjects (e.g. statistic, differential calculus, mathematical equations, linear regression, exponential growth etc.)" (teacher 52)

Teachers in social science primarily conceptualised their subject in terms of products, which is a little surprising: one might expect more of a process-orientation with their strong purpose-orientation towards Civic Literacy. Danish teachers balanced products and processes in their responses.

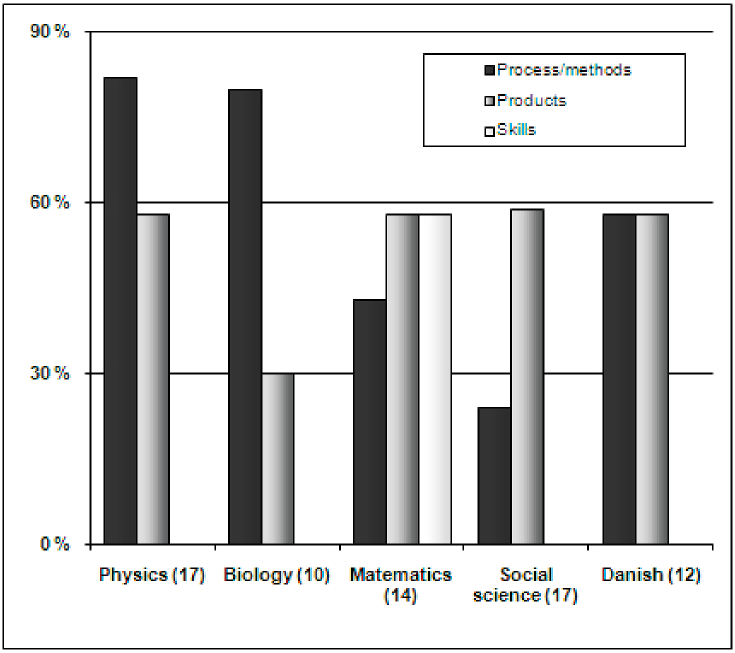

Figure 3. Teachers' mentioning of product- and process aspects in their description of subjects/ disciplines.

An interesting process-related aspect is that more than half of the physics teachers made reference to '*The* Scientific Method' (singular form). Generally, very few of the teachers expressed philosophy of science-informed views about the nature of science, but a closer inspection of the essays reveals that conceptions of *The Scientific Method* are related to Popperian beliefs in hypothetical-deductive method and falsification (e.g. Godfrey-Smith, 2003). A similar "falsificationist" view of science can be found in the curriculum-description for all science subjects in upper secondary. Apparently, the physics teachers were easily aligned with such conceptions. Across the sciences some instances of logical positivism have been found in the essays, while 'the sociological turn' (e.g. Kuhn, Latour, ibid.) in philosophy of science is absent from the sample.

4. Conceptions of interdisciplinary teaching and the role of the subject

With a few exceptions (4%) all the participating teachers expressed a positive view on interdisciplinary teaching and collaboration with other subjects. However, most of the teachers wrote about collaboration from a subject-oriented perspective. Thus a physics teacher wrote:

> "Physics can contribute to the construction of models (e.g. models of climate, energy supply) which acts as a qualified basis for interdisciplinary teaching with other subjects, like social science etc. In particular, physics can collaborate with mathematics, chemistry, biology (the other exact subjects)." (teacher 13).

From a subject-oriented perspective interdisciplinary work should be grounded on traditional subject matter but with the extension of some extra perspectives. Only a smaller fraction (approx. 15%) of science teachers described interdisciplinary projects as an integration of subjects around real-life-issues. Thus a biology teacher wrote:

> "Collaboration with science in general is extended. Gradually, they tend to be doing only biological oriented practicals. Physical education is a natural partner, in topics like performance-enhancing, health aspects and prevention of injuries. Previously, we have made course-modules on anorexia, plastic surgery, self-esteem etc. with the subject Danish as partner. Geography is the abiotic part of biology, which makes it a frequent partner. All carbon-chemistry (organic) is taught within biology, but in-organic parts of chemistry provide useful support, as does to a lesser extent mathematics, when a problem calls for calculation…" (teacher, 10)

The fact that only a few science teachers mentioned topics outside their traditional subject as interesting in relation to interdisciplinary teaching is probably linked to the fact that very few of the teachers saw topics relating to students' interests and everyday life as factors of importance for students' learning.

Depending on the subject, teachers have different conceptions of interdisciplinary teaching. One extreme is provided by the mathematics teachers where not even a single teacher stated a subject-transcending integrated perspective. The other extreme is social science and Danish teachers, who almost exclusively expressed an integrated perspective – only 10% of these teachers identified their main focus as subject learning. Biology and physics teachers positioned themselves somewhere in between, approximately 50% of teachers in these subjects expressed views corresponding with a subject-oriented perspective; while 25% expressed views corresponding with an integrated position.

Implications for teacher engagement in cross-curricular reform

We will now discuss our empirical findings against the demands embedded in the recent reform of upper secondary school ('Alment gymnasium', stx) – in particular its new emphasis on interdisciplinary teaching and meta-perspectives on knowledge (e.g. science as a particular form of knowledge with certain strengths and limitations). Our analysis has established some characteristics shared by the participating science teachers and some more subject specific 'flavours'. Both elements will be of importance to teachers' engagement in the reform.

Shared CTCs of importance for teachers' engagement in reform

All teachers in this study have positive attitudes towards one or more kinds of interdisciplinary teaching, and from a reform-implementation perspective this is quite promising. However, only 15% of the science teachers expressed a view where real-life issues and problems were central for students' learning, as they are intended to be in the new interdisciplinary curricula. Furthermore, many science and all math teachers did not transcend a subject perspective when they wrote about interdisciplinary teaching. This focus on traditional subjects tend to complicate teachers' engagement with the reform, and may contribute to the identified dislike of AT experienced by many science teachers (Danmarks Evalueringsinstitut, 2009b).

Application of *subject matter knowledge* (SMK, Shulman, 1986) is an important indicator of learning in all subjects. So, cross-curricular innovations like AT may be seen as a new arena to unfold applications of SMK. However, in AT applications are determined by the problem being investigated instead of subject demands. This may frustrate the more subject-oriented teachers.

Many teachers do not distinguish between academic disciplines and school subjects, and only a few acknowledge the different institutional aims, which is an unsettling unreflective starting point for teachers work with AT. Furthermore, many science teachers will find it difficult to include aspects of philosophy of science in their teaching of AT since only a few expressed philosophy of science informed and contemporary views on the nature of science. This corresponds with the need to improve teachers' insights in this area already stressed in the report evaluating the first cycle of AT (Danmarks Evalueringsinstitut, 2009a, p.28)

Finally, many upper secondary science teachers tend to build their professional identity around their teaching subjects: some 60 % of the teachers in our sample explicitly make such 'tribal'-identification. Teachers in Danish upper secondary school have as part of their education been through an enculturation process into academic science, and it has shaped their identities. This ensures engagement in traditional subject teaching, but may counteract interdisciplinary teaching, challenging both their traditional CTCs and their subject-based identity.

Subject-specific CTCs and reform engagement

An important finding from this exploratory study is that science teachers CTSs have subject specific 'flavour', and we hypothesize that some of the differences in CTCs will influence the way teachers' from various subjects will engagement in cross-curricular collaborations:

1. Different conceptions of purpose may constitute barriers to interdisciplinary collaboration, assuming that cross-curricular teaching of a more integrated nature can only be sustained when the participating teachers have similar conceptions of purposes of teaching their subject:
   - Biology teachers have a clear civic literacy-orientation in their purposes, which seem to provide a perfect grounding for working with socio-scientific issues, real-life risk and decision-making and the relation between evidence and claims to knowledge. With this emphasis biology teachers more or less coincide with the emphases of teachers from social science – and obviously these two subjects would be a convenient match for cross-faculty cooperation in subjects like AT.
   - The mathematics teachers emphasise the purpose of providing a 'solid foundation' for other subjects and further studies. This could be read as an invitation to cross-curricular collaboration, but at the same time these teachers only speak of interdisciplinary teaching from a subject-oriented perspective. With this narrow emphasis, mathematics teachers might have considerable difficulty in engaging in the reform initiatives.
   - The physics teachers appear to have a broader range of more moderate emphases, which suggests that they could engage pretty flexibly in cross-curricular teaching and still have priorities fulfilled. Physics teachers in this sample are the closest match to teachers of Humanities (Danish, in the sample) in their orientation towards Bildung. This broad orientation among physics teachers of the sample may be seen as a response to decades of criticism of physics teaching and physic's struggle for legitimization.

2. When it comes to differences in curriculum emphasis and pedagogy other CTCs are actualized:
   - The profound blurring of academic discipline and school subject found among many teachers is particularly strong among biology teachers. It may be related to the origin of biology as Natural History, where academic fields and forms of knowledge were only weakly demarcated from everyday knowledge. This would construe biology as more inclusive than the other science subjects.
   - In this study very few science and mathematics teachers state that learning is facilitated by content being relevant to students' everyday lives and interests. Relevance to students is therefore not likely to be prioritized when science teachers select content for interdisciplinary teaching. In contrast half of the social science teachers identify student relevance as an important aspect of learning.
   - Only a few teachers in our sample can be characterized as constructivists. But teachers from science and mathematics emphasized the value of student activities, and their commitment to interdisciplinary teaching will probably depend on the possibility to integrate subject-relevant activities.
   - *Problem-solving ability* is an indicator of students' learning and an important aspect of physics and mathematics in school (closed problems). In other words: these subjects have a shared interest which might be cultivated in collaboration between the two. Biologists, on the other hand, tend to prefer a 'softer' pedagogy including open

tasks and discussions (students formulating problems, having discussions and producing written responses), and some biologists also mention students' affective learning outcomes. These differences among physics and biology teachers match the findings in Krogh (2006). Biology teachers' CTCs seems to comply well with conceptions held by teachers in social science and Danish, indicating a common ground for integrating pedagogies e.g. project-work.

- Most teachers of physics (and some mathematicians) describe a lesson structure with a gradual movement from transmission of knowledge ("telling") towards more student-centred activities ("application"). This pattern is not apparent in the responses from biology teachers. This *telling-applying-approach* is not compatible with a teaching based on students' project work; it would only be suitable for cross curricular collaboration based on parallel teaching.

Changing CTCs in favour of teachers' reform engagement

Our study has identified areas where the CTCs of science and math teachers are discordant with conceptions embedded in the 2005 reform. The critical consideration now is how teacher development can be achieved to facilitate the implementation of reform intentions.

Teachers' CTCs may be made available to their own reflection with a methodology like the one applied in this exploratory study. Writing essay-responses to fundamental core questions serves the purpose of *explication* of CTCs and provides a starting point for reflection and/or discussion in groups of teachers and/or teacher-trainers. The exact number and phrasing of core questions may be adjusted, but it might be useful to maintain the key-elements of the present work, making it possible to use our analytical categories and results as a point of reference for joint analysis and discussion.

CTCs are central parts of science teachers' belief-system, and as such they may be difficult to change. Inspired by the research on cognitive (conceptual) change we would suggest *confrontation* as another strategy to try to improve teachers' CTCs. Helping teachers to experience a tension between their CTCs and the intentions outlined in the reform initiative, may establish a need and initiate a process leading teachers' towards a revision of their CTCs. Real change, however, should only be expected when new conceptions are perceived plausible and proven fruitful in the teacher's own practice. The complex interaction between professional experimentation and belief change must be utilized for this purpose (Clarke & Hollingsworth, 2002).

Information on teachers' CTCs can be used to target developmental activities in relation to the curriculum reform. The analysis presented in this paper suggest a number of subject specific issues, e.g. that physics teachers might benefit from courses in how science really works, while biology teachers in particular should be given more opportunity to reflect on the relationship between biology as an academic discipline and a school subject, and mathematicians' internalist views of cross-curricular participation should be challenged.

Concluding remarks

This study has expanded previous studies on teachers' CTCs in the sense that it both explores 'the whole range' of CTCs and does that across the curriculum. The broad approach has provided insights into (science) teachers' CTCs and particularly it has substantiated subject specific aspects of these.

Teachers' adaptation and implementation of new curricula is shaped by their central beliefs, and we have discussed how general and subject specific CTCs might interfere with new intended curricula of upper secondary school. Some evidence of this actually happening has been indicated.

Finally we have suggested simple methods and strategies to improve teacher awareness and reflexivity in relation to (their own) CTCs. These might be a useful starting point from a personal teacher development perspective as well as an "enact-the-change-policies-of-the-system"-perspective (Clarke & Hollingsworth, 2002). Fundamentally, we believe that only by assessing and addressing CTCs in addition to other aspects of pedagogic content knowledge and subject matter knowledge we will be able to meet the call for a "Renewed pedagogy for the future of Europe", including the demands of the new Danish reform initiatives.

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Per Högström har doktorsexamen i pedagogiskt arbete och arbetar både som grundskollärare i naturvetenskapliga ämnen och som lärarutbildare vid Luleå tekniska universitet.

Christina Ottander har doktorsexamen i fysiologisk botanik och är universitetslektor i naturvetenskapernas didaktik. Hennes forskningsintresse handlar om laborativt arbete i biologi samt elevers kunskapsutveckling vid arbete med samhällsfrågor med naturvetenskapligt innehåll.

Sylvia Benckert är universitetslektor i fysik och docent i fysikdidaktik. Hennes forskningsintressen handlar framförallt om gruppdiskussioner i fysikundervisning och om genusaspekter på naturvetenskap.

PER HÖGSTRÖM
Institutionen för naturvetenskapernas och matematikens didaktik, Umeå Universitet, Institutionen för tillämpad kemi och geovetenskap, Luleå Tekniska Universitet per.hogstrom@ltu.se

CHRISTINA OTTANDER
Institutionen för naturvetenskapernas och matematikens didaktik, Umeå Universitet
christina.ottander@matnv.umu.se

SYLVIA BENCKERT
Institutionen för fysik, Umeå Universitet
sylvia.benckert@physics.umu.se

Laborativt arbete i grundskolans senare år: Lärares perspektiv

Abstract
In this paper we describe the results from interviews with science teachers in lower secondary school. The teachers were asked what they wanted to achieve with laboratory work, what difficulties they experienced and if there were any differences between lab work in biology, chemistry and physics. The results show that the teachers wanted lab work to help the students develop their understanding, to make them interested and to develop their laboratory skills. Some of the teachers described lab work that included scientific inquiry but not, specifically, knowledge about how to systematically investigate phenomena in nature. Aspects of nature of science were rare. Lack of time to discuss with the students during lab work was seen as one difficulty which resulted in problems for students to link observables to scientific ideas. Laboratory exercises in chemistry were often regarded too abstract while lab work in physics and biology were much easier to link to everyday life.

Bakgrund
Laborativt arbete anses vara av stor betydelse för elevers lärande i naturvetenskap (Leach, 1998; Lunetta, Hofstein & Clough, 2007; Wellington, 1998). De erfarenheter som elever får genom laborationer är, enligt Hodson (2001) och Millar (2004), till och med nödvändiga i den naturvetenskapliga undervisningen. Däremot påpekas i flera studier att laborativt arbete i skolpraktiken alltför ofta fokuserar på själva genomförandet snarare än på vad eleverna kan lära sig av detta (Hodson, 1990; 1991; Hofstein & Lunetta, 2004; Millar, Tiberghien & Le Maréchal, 2002). Elever ställs ofta inför en mängd svårigheter som gör att målen med laborationerna inte uppfylls

(Abrahams & Millar, 2008; Hodson, 1991; 1996). Ytterligare beskrivningar av positiva effekter av laborativt arbete samt redovisade svårigheter med måluppfyllelse beskrivs nedan.

Enligt Jenkins (1999) och Wellington (1998) kan mål för laborativt arbete delas in i tre huvudområden. Det första handlar om att hjälpa elever att förstå naturvetenskapliga begrepp, fenomen och modeller. Det andra handlar om att utveckla elevers intresse för naturvetenskap ofta genom att flera sinnen är inblandade. Det tredje gäller laborativa färdigheter och arbetssätt och innebär att eleverna ska lära sig att hantera utrustning som brännare och olika typer av mätinstrument, sådana färdigheter som i vardagligt tal kallas för labvana. I en översiktsartikel tar Hofstein och Lunetta (2004) upp samma mål men lägger till att laborativt arbete även ger möjligheter att träna problemlösningsförmåga, ger erfarenheter av naturvetenskapliga undersökningsmetoder och ökad förståelse av naturvetenskapens karaktär.

Ett stort Europeiskt projekt (Labwork in Science Education) genomfördes under 1990-talet för att öka kunskaperna om lärares mål med praktiskt arbete och hur de implementeras i undervisningen. Resultaten visar att lärare från gymnasium och universitet angav att de viktigaste målen för det laborativa arbetet var: att underlätta förståelse av teori, att utveckla ett vetenskapligt sätt att tänka och att utveckla experimentella färdigheter (Welzel et al., 1998). Med ett vetenskapligt tänkande menar de att lära sig planera experiment och att kritiskt granska resultat. Andra studier visar att det laborativa arbete som genomförs i skolpraktiken till största delen handlar om att samla mätdata, illustrera fenomen och att hjälpa elever att förstå vissa begrepp (Abrahams & Millar, 2008; Leach, 1998). Högström, Ottander och Benckert (2006) visar att lärares mål med laborativt arbete i den svenska grundskolan, skolår 7-9, är att utveckla förståelse av begrepp och fenomen, att tänka och reflektera kring det laborativa arbetet, att anknyta till vardag och verklighet, att utveckla praktiska laborativa färdigheter samt att intressera och roa.

Lärare på gymnasium och universitet beskriver en viss skillnad mellan laborativt arbete i biologi och fysik (Welzel et al., 1998). I biologi anses mål som syftar till att hjälpa studenter att lära sig vetenskapliga sätt att tänka vara viktigast. I fysik anses det viktigast att praktiskt arbete underlättar förståelse av teori. I övrigt finns få studier som visar på likheter och skillnader i det laborativa arbetet mellan de olika ämnena. Vissa elever i den svenska grundskolan uppfattar att de i fysik och kemi oftast följer instruktioner, medan det i biologi är oklart för eleverna vad som är laborativt arbete eller om det ens genomförs laborationer (Lindahl, 2003).

Ett undersökande arbetssätt förespråkas som en viktig metod i naturvetenskaplig undervisning (Bybee, 2000; Hofstein & Lunetta, 2004). Två Europeiska rapporter (EU, 2007; Osborne & Dillon, 2008) argumenterar för att ett sådant arbetssätt är effektivt och väcker elevers intresse. Abd-El-Khalick et al. (2004) konstaterar att ett undersökande arbetssätt, ”scientific inquiry”, idag är en central term i retoriken rörande den naturvetenskapliga utbildningen. Målen för det undersökande arbetssättet är enligt Abd-El-Khalick dels att eleverna bättre ska förstå naturvetenskapens innehåll och dels att de ska lära sig att göra vetenskapliga undersökningar och samtidigt utveckla sin förståelse av naturvetenskapens karaktär. Dessa mål är vittomfattande och i artikeln visas att det finns en stor variation i vad olika forskare och läroplansutvecklare lägger in i begreppet. Bybee (2000) beskriver att arbetssättet tränar eleverna att agera på ett vetenskapsliknande sätt och ökar elevernas förståelse av vetenskapsliknande undersökningar. Eleverna ges möjlighet att lära sig hur man systematiskt undersöker fenomen i naturen, föreslår och testar hypoteser och underbygger påståenden genom belägg från undersökningar. Även om detta anses vara viktigt poängteras att vanliga skollaborationer i alltför liten grad liknar autentiska naturvetenskapliga undersökningar (Chinn & Malhotra, 2002; Johnstone & Al-Shuaili, 2001). Till exempel skriver Chinn och Malhotra (2002) att elever alltför sällan får möjlighet att göra undersökningar som utgår från deras egna frågor. Svårigheterna med att göra vetenskapsliknande undersökningar kan bero på att lärare och elever har lite erfarenhet av autentiska undersökningar och att skolorna ofta saknar utrustning och material (Hofstein & Lunetta, 2004; Johnstone & Al-Shuaili, 2001; Millar, 2004).

Naturvetenskapens karaktär är också något som eleverna bör ha kännedom om. Det innebär att eleverna ska känna till hur naturvetenskaplig kunskap uppkommer, hur forskare arbetar och hur naturvetenskapen utvecklats historiskt (Osborne, Collins, Ratcliffe, Millar & Duschl, 2003). En studie av Schwartz, Lederman och Crawford (2004) visar att undersökande arbetssätt är en lämplig metod för att ge eleverna möjligheter att ta till sig naturvetenskapens karaktär under förutsättning att lärarna själva har goda kunskaper både om naturvetenskapliga undersökningar och om naturvetenskapens karaktär. Lederman påpekar i Abd-El-Khalick et al. (2004) att det bästa sättet att undervisa om naturvetenskapens karaktär är att låta eleverna göra undersökningar och sedan reflektera över dessa aktiviteter och vilken naturvetenskaplig kunskap som kommit fram genom undersökningen.

Det är svårt att uppfylla alla viktiga mål för laborationerna och det är svårt att konstruera bra laborationer. Elever har ofta problem med att identifiera, tolka och värdera resultat. Läraren måste då hjälpa till att förklara för eleverna vad som är viktigt att observera (Kanari & Millar, 2004) eller hjälpa till att förklara hur laborationen ska genomföras (Amerine & Bilmes, 1990). Andra exempel på svårigheter visas i en studie som undersökte på vilket sätt 25 laborationer genomfördes i ämnena biologi, fysik och kemi (Abrahams & Millar, 2008). Författarna konstaterar att lärarna ansåg att det var viktigt att eleverna lärde sig det naturvetenskapliga innehållet utifrån laborationen, men lärarna hade inte någon plan för hur eleverna skulle lära sig de mer övergripande idéerna och de undervisade inte heller om hur det skulle gå till. Det verkade som om många lärare trodde att eleverna skulle lära sig idéerna mer eller mindre direkt från observationer och mätningar.

Många faktorer kan påverka vilket lärande som sker under det laborativa arbetet. Domin (1999) hävdar att laborationsinstruktionen har stor betydelse för vilket lärande som sker. Lindwall (2008) visar i sin avhandling att laborationer som på ytan ser likadana ut ändå kan ge olika lärande eftersom detaljerna i ämnesinnehållet varierar. Andra författare visar att läraren är mycket betydelsefull då denne, genom sin kommunikation och interaktion med eleverna, förmedlar laborationens idéer (Driver, 1995; Högström, Ottander och Benckert, 2009; Lunetta et al., 2007). Emily van Zee och Jim Minstrell (1997) konstaterar i sin studie av laborativt arbete i fysik att lärarens frågor ofta hjälper eleverna att utveckla det egna tänkandet. De frågor som ställs till eleverna visar samtidigt vad läraren anser viktigt att eleverna ska förstå, dvs. lärarens intentioner framträder i frågorna. Högström et al. (2009) visar att det eleverna uppfattar som viktigt inte bara är beroende av explicit uttryckta mål utan även av diskussioner och agerande under laborationerna. Det innebär att målen inte alltid måste vara explicit uttalade för att eleverna ska uppfatta vad som är viktigt att lära. Lärarnas agerande under laborationerna kan framhäva andra mål än de som lärarna explicit anger.

I den svenska grundskolans senare år undervisas ämnena biologi, fysik och kemi både separat och integrerat. Lärarna undervisar ofta i alla ämnen och därför benämns dessa som NO-lärare. Benämningen betyder inte att de bedriver en integrerad NO-undervisning. NO-lärarna har stora friheter att utforma den egna undervisningen på sätt de anser vara lämpliga och med mål de anser vara viktiga, vilket även gäller för det laborativa arbetet i NO.

Enligt beskrivningen ovan är följande mål för det laborativa arbetet viktiga att utveckla: kunskap och förståelse; intresse för naturvetenskap; laborativa färdigheter; kunskap om naturvetenskapliga undersökningar och om naturvetenskapens karaktär. I denna studie undersöker vi om det är dessa mål som anses viktiga av lärarna i den svenska grundskolan eller om det är annat de vill uppnå med sina laborationer. Följande frågor fokuseras:

- Vad vill lärarna uppnå med det laborativa arbetet i NO?
- Finns mål med anknytning till undersökande arbete och naturvetenskapens karaktär i lärarnas beskrivningar av vad de vill uppnå med laborationerna?
- Vilka svårigheter med det laborativa arbetet uppmärksammas av lärarna?
- Vilka skillnader mellan laborationer i ämnena biologi, fysik och kemi beskriver lärarna?

Metod och genomförande

I denna studie deltog sju NO-lärare, som undervisade på årskurs 7-9 i grundskolor i norra Sverige. Tre av de deltagande lärarna hade även deltagit i en tidigare studie (Högström et al., 2006). Bland dessa försökte vi välja lärare som beskrivit olika sätt att arbeta laborativt. För att få med flera lärare tillfrågades ytterligare fyra NO-lärare om de ville delta i studien. De sju NO-lärarna, som slutligen deltog i studien, hade flerårig erfarenhet från undervisning med inslag av laborativt arbete i ämnena biologi, fysik och kemi. Det var både kvinnliga och manliga lärare och de representerade flera skolor (se Tabell 1).

Först genomfördes en bandinspelad pilotintervju med en lärare för att prova och utvärdera en intervjuguide. Efter justeringar användes denna intervjuguide i intervjuerna (se bilaga 1). NO-lärarna intervjuades under ca en timme vardera, varefter intervjuerna transkriberades i sin helhet. Intervjuerna med lärarna var semistrukturerade och kännetecknades av en samtalsliknande diskussion omkring intervjufrågorna. Intervjufrågorna var inriktade på laborationer i lärarens egen undervisning. Lärarna fick berätta relativt fritt om sina uppfattningar och reflektera över sådant de ansåg var relevant. Intervjupersonerna fick sedan läsa transkripten och fick möjlighet att kommentera och komplettera sina uttalanden. Samtliga intervjuer genomfördes av den förste författaren.

Analysen av intervjuerna genomfördes i flera steg. I en inledande analys noterade var och en av författarna tolkningar och reflektioner runt intervjutranskripten. Detta gav en överblick över hela datamaterialet och utgångspunkter för vidare analys för att besvara forskningsfrågorna. I den vidare analysen ställdes frågor till datamaterialet. För att identifiera uttalanden med anknytning till undersökande arbete, analyserades om lärarna beskrev att eleverna skulle genomföra observationer, ha egna frågeställningar, söka information själva, ställa hypoteser, förmedla resultat och föreslå förklaringar. Ett motsvarande tillvägagångssätt utnyttjades för att ta reda på om lärarnas uttalanden innehöll några anknytningar till naturvetenskapens karaktär, det vill säga något om kunskapens utveckling, forskares arbete och historisk utveckling. Därefter gick vi igenom transkripten ytterligare en gång för att identifiera lärarnas beskrivning av svårigheter med laborationer och skillnader med det laborativa arbetet mellan de olika ämnena.

NO-lärarnas beskrivningar av vad de vill uppnå med laborativt arbete sammanställdes utifrån transkripten som korta berättelser i likhet med Hansson och Redfors (2006). Uttalade upprepningar och intervjuarens röst utelämnades ur berättelserna som ligger nära det respektive lärare sade under intervjun. De olika lärarnas berättelser illustrerar de resonemang och de synsätt som framträdde vid intervjuerna. I resultaten återges två berättelser som illustrerar vad lärarna vill uppnå.

Tabell 1. Presentation av NO-lärare ingående i studien, samtliga undervisar i de naturvetenskapliga ämnena biologi, fysik och kemi i grundskolans senare år (7-9). Lärarnas namn är fingerade.

NO-Lärare	Erfarenhet	Skola	Intervjutid	Tidigare intervjuad
Berit	7 år	A	56 min	Ja
Julia	35 år	B	39 min	Ja
Diana	14 år	C	43 min	Ja
Lotta	12 år	D	52 min	Nej
Magnus	9 år	D	47 min	Nej
Curt	14 år	A	38 min	Nej
Hanna	6 år	A	45 min	Nej

Resultat

I resultaten nedan visas hur lärarna beskriver laborativt arbete och vad de vill uppnå med laborationerna, vilka svårigheter de ser i den egna undervisningen och vilka skillnader mellan ämnena de uppfattar.

Vad vill lärarna uppnå med laborationerna?

Alla NO-lärarna beskriver att laborationer i stor utsträckning används för att eleverna ska lära sig om naturvetenskapliga fenomen, fakta och begrepp. Tre av lärarna beskriver att eleverna också ska lära sig praktiska laborativa färdigheter och därmed skaffa sig labvana. De flesta lärarna lyfter fram att laborativt arbete kan medföra att eleverna blir mer intresserade av NO. De ser detta som ett delmål för laborationerna men inte som ett viktigt mål. Användning av ett undersökande arbetssätt beskrivs utförligt av en av lärarna och finns med som inslag i laborationsundervisningen hos flera av de andra lärarna. Endast en av lärarna tar med aspekter med anknytning till naturvetenskapens karaktär.

Laborationer ska öka förståelsen

> Jag vill att laborationer ska öka förståelsen. Min upplevelse av många labbar, speciellt i kemi, är att man ser att något händer men man förstår inte. Man har gjort en massa labbar för att de står i boken och för att man har alltid gjort på det sättet. Då förstår eleverna inte riktigt varför de ska göra laborationerna. Det är såklart viktigt att eleverna har provat labba någon gång på högstadiet, men jag ser inte det som ett motiv för att göra en massa labbar. Det jag kan känna är att jag vill hitta bra labbar, speciellt i kemi, som är tydliga och som kan öka förståelsen och inte bara visa att något händer. Eleverna har däremot inte samma tanke som jag, att vi ska labba för att förstå bättre, bara det smäller tycker eleverna det är bra. Jag vill hitta bra grejer som samtidigt gör att eleverna tycker att det blir roligare. (Berit)

För Berit är elevernas förståelse viktig men det uppnås inte med vilka laborationer som helst. De som genomförs av gammal vana eller för att de står i boken är inte tillräckliga. Eleverna måste veta varför de ska göra laborationerna. Berit vill att laborationerna ska vara både roliga och lärorika. Hennes uttalanden illustrerar vad flera av de andra lärarna uttryckte. Sex av de sju lärarna sade att eleverna på något sätt skulle öka sin förståelse i naturvetenskap genom laborationerna.

Laborationer ska intressera och roa

Enligt citatet ovan vill Berit att laborationerna ska vara både roliga och lärorika. De flesta lärarna anser, precis som Berit, att eleverna ska bli mer intresserade av NO genom det laborativa arbetet. En av lärarna säger till exempel att det blir rätt tråkigt att bara läsa NO teoretiskt och att laborationerna är till för att göra NO mer intressant och roligt. Att öka elevernas intresse uttrycks emellertid inte som ett huvudsakligt mål av någon av lärarna.

Laborationer ska ge laborativa färdigheter

Tre av lärarna beskriver att eleverna ska lära sig praktiska laborativa färdigheter och därmed skaffa sig labvana. Det innebär enligt lärarna att till exempel veta hur mycket vätska som ska hällas i ett provrör för att det ska bli en lämplig mängd eller att veta hur man ska hantera en brännare. Dessutom ingår sådana färdigheter som har att göra med elevernas förmåga att följa en manual och samarbeta i grupp. När laborativa färdigheter diskuteras under intervjuerna uttrycker lärarna att det är en del av det laborativa arbetet, men ingen av lärarna betonar att det är särskilt viktigt. En lärare menar att eleverna får labvana efter några gånger på lab, medan en annan tycker att färdigheter i att laborera och experimentera inte är till så stor nytta för många elever på längre sikt:

> De här eleverna som siktar på att gå natur [naturvetenskapligt program i gymnasieskolan], det är ju bra om de har lite färdigheter så att de inte känner sig underlägsna när de kommer till gymnasiet. Men många av dem har inte så stor användning av det egentligen. (Magnus)

Enligt flera av lärarna är de laborationer, som genomförs i årskurs sju, ofta enklare att genomföra och mer inriktade mot att eleverna ska få labvana än laborationerna under årskurs åtta och nio då laborationerna är mer inriktade på förklaringar till naturvetenskapliga fenomen.

Ett undersökande arbetssätt

> Det står klart och tydligt i kursplanerna att eleverna ska kunna planera och genomföra laborationer. Det de då framförallt får göra är att ställa upp en hypotes och sen får de testa den. Då är det upp till eleverna att fundera ut, vad är det för grejer jag behöver? Vad kan jag göra? Till exempel när de håller på att kolla metallerna i spänningsserien så ligger en del av metallerna så pass nära varandra att eleverna knappt ser någon skillnad mellan dem. Om metallerna är omkastade då får eleverna diskutera felkällor, som vad det kan bero på. Då kan de testa igen och se efter om det blir annorlunda. Då kan de komma fram till att voltmetern de använde kanske inte var så noggrann, eller att metallen kanske inte var så bra putsad. Samtidigt är det naturligtvis bra om eleverna, utifrån vad de kollat på, kan dra några slutsatser. (Julia)

Julia beskriver att eleverna ska ges möjlighet att planera arbetet själva. Här skiljer sig Julias uttalande från flera av de andra lärarna. Till exempel säger tre av lärarna att de aldrig tänkt på att laborationer kan genomföras med elevers planerande som utgångspunkt.

Fyra av lärarna beskriver emellertid exempel på laborationer som innehåller moment där elever ges möjlighet att planera delar av laborationerna och genomföra dessa utifrån egna funderingar. Dessa lärare vill uppnå det Julia beskriver, men de uttrycker det inte lika ambitiöst. I en laboration i ellära får eleverna i uppgift att bygga en fungerande ringklocka. De får förklara varför ringklockan fungerar och ändra ljudet genom att ändra olika parametrar som till exempel strömstyrkan. Allt eleverna har till sin hjälp är en bild på en konstruktion av en ringklocka. I en annan laboration får eleverna undersöka vad som påverkar svängningstiden för en pendel.

Flera lärare beskriver att enkla laborationer är en bra väg in i nya kunskapsområden genom att de ger eleverna inspiration och väcker frågor hos eleverna. Dessa frågor kan undersökas vidare i ytterligare försök. Lottas beskrivning nedan ger en illustration:

> Jag gillar enkla laborationer som kan ha en hur djup förklaring som helst egentligen. Jag tycker inte att man ska krångla till labben. Den ska vara enkel att utföra men den ska ställa tusen frågor ändå. Till exempel i optik, då kan eleverna ha ett kryss och en prick på ett papper för att se var blinda fläcken är. Eleverna upptäcker att de har en blind fläck som de inte ens visste om att de hade. (Lotta)

I någon mån finns ett undersökande arbetssätt med i flera av lärarnas repertoar av laborationer. Lärarna tycker i allmänhet att det är svårt att ge elever möjlighet att planera egna laborationer och att hjälpa eleverna att få insikt i hur experiment kan utformas och hur resultat kan analyseras.

Kunskap om naturvetenskapens karaktär

Ingen av lärarna nämner kunskap om naturvetenskapens karaktär explicit under intervjuerna. Däremot beskriver en av lärarna, Magnus, ett experiment med en pendel där aspekter med anknytning till naturvetenskapens karaktär visas indirekt. Läraren anser att Galileis historiska pendelexperiment kan upprepas av eleverna som ett exempel på hur naturvetenskapen fungerar. Nedan presenteras ett kort utdrag från den dialog som fördes med läraren under intervjun.

> Intervjuare: Är det en viktig del av det laborativa arbetet också? Att se att naturvetenskapen innehåller experiment?
> Magnus: Ja, det är det ju. Och kanske förklara att det är ju faktiskt så vi har kommit på det vi vet nu. Det är ju tack vare att folk har gjort experiment.
> Intervjuare: Är det någonting som eleverna och du diskuterar tillsammans?
> Magnus: Ja, det försöker jag. Och även att misslyckade experiment har fört vetenskapen framåt som dom experiment som har lyckats.

Flera av de andra lärarna diskuterar med eleverna om det som händer under laborationerna, men diskussionen används inte för att hjälpa eleverna att utveckla kunskap om naturvetenskapens karaktär. En av lärarna beskriver dock vikten av att eleverna får reflektera vidare över resultaten i laborationerna.

> Jo, men där tror jag nog att jag är ganska bra på att få dom att inte fastna i just den specifika händelsen vi håller på med. Jag tror att det är genom det ständiga samtalet och i de ständiga försöken att få dom att iaktta och få dom att förstå omvärlden och det som dom ser. Om man får dom att ha en ständig reflektion kring det… och det är inte så lätt. (Curt)

Denna typ av reflektion kan leda till diskussioner om naturvetenskapens karaktär. Vi har dock inte sett några tydliga exempel på detta i intervjumaterialet.

Svårigheter med det laborativa arbetet

NO-lärarna beskriver olika typer av svårigheter med laborationerna. Vissa svårigheter är mer framträdande genom att de beskrivs av flera lärare. Hit hör svårigheten att ge eleverna möjlighet att *planera egna laborationer*. Övriga svårigheter som uppmärksammas är att *hantera omgivande faktorer* (material, utrustning, lokaler, gruppstorlek) och att ge laborationerna *tillräckligt med tid*. Ett par lärare säger att *vissa kunskapsområden* kan vara svåra att laborera omkring, till exempel genetik och atomfysik.

Lärarna anser i allmänhet att det är *svårt att ge eleverna möjligheter att planera egna laborationer* och att hjälpa dem att få insikt i hur experiment kan utformas och hur resultat kan analyseras. Enligt en lärare beror detta problem på att elever i årskurs sju ges för lite tid till laborativt arbete. Läraren anser att elever i årskurs sju inte har tillräckligt med kunskaper om laborativt arbete för att kunna planera egna undersökningar. Läraren säger att elever i årskurs sju borde göra fler laborationer som dels ger dem mer erfarenhet och dels uppmärksammar betydelsen av deras eget tänkande.

Förutsättningarna för det laborativa arbetet påverkas av *svårigheter att hantera omgivande faktorer*. En lärare anser att schemaläggning kan påverka vad som är genomförbart.

> Jag skulle vilja se den person som mikroskoperar i hel klass i sjuan, när det är mellan 25 och 30 ungar som ska hinna se rätt saker och ställa in mikroskopen. Det blir svårt att se att de klarar det… då har de inte lärt sig att hantera mikroskopet ordentligt. Då har du egentligen bara demonstrerat hur man gör. Du får ändå gå runt och se efter om de verkligen har skärpan på rätt saker. Eller sitter eleverna bara och tittar på luftbubblor? (Julia)

Julia anser att det är nödvändigt med möjligheter till arbete i halvklass i biologi, annars är det svårt att se vad eleverna lär sig och att hinna hjälpa alla. Vid Julias skola är schemat organiserat så att det, enligt henne, inte finns ordentliga möjligheter till arbete med halv klass för att utveckla elevers laborativa färdigheter.

Bristen på tid för samtal med eleverna under genomförandet av laborationerna är en annan svårighet som flera av lärarna diskuterar. De önskar att de hade mer tid att tala med eleverna om naturvetenskapligt innehåll, om processer som leder fram till ett visst resultat och om arbetssätten som leder fram till resultaten. Lärarna beskriver till exempel att eleverna skulle kunna få ut mer av laborationerna om mer tid lades på att diskutera laborationernas upplägg och att reflektera över resultaten. Fyra av lärarna säger att elevernas rapporter ibland visar hur de tänker, men de önskar att eleverna i högre utsträckning borde få möjlighet att också prata om sina reflektioner. De ser rapporten som viktig, men det behövs även tid för muntlig reflektion.

> Vissa fasta delar är bara att skriva ner. Vad man använt för material och hur man har gått tillväga… Men den där reflektionsdelen på slutet är den som visar i vilken grad eleverna har förstått den här uppgiften och vad de har dragit för slutsatser av den. (Diana)

Skillnader mellan ämnena

Resultaten visar att flera av lärarna ser många möjligheter att arbeta laborativt i fysik, medan kemilaborationer ofta ses som relativt problematiska. Laborationer i biologi tar längst tid att genomföra och är, enligt tre lärare, det ämne man laborerar minst i.

Flera av lärarna anser att det är lättare att göra laborationer konkreta i fysik än i de andra ämnena. Fem av NO-lärarna anser att det med hjälp av *enkla* laborationer i fysik går att illustrera fenomen, jämföra med sammanhang i det verkliga livet, se vad som händer och få fram resultat. NO-läraren Magnus beskrivning nedan får illustrera flera lärares sätt att uttrycka sig om laborationer i fysik.

> Tar man två bilar och rullar över kanten på ett bord så är det lättare att förstå att de kommer att krascha i backen. Den ena, som håller högre fart, kan man lista ut att den kommer att fara lite längre fram än den andra. Så att det är nog lite lättare för eleverna att föreställa sig vad som kommer att hända inom fysiken. (Magnus)

Fyra av lärarna anser att laborationer i kemi upplevs som problematiska eftersom de innehåller så många abstrakta begrepp. Framförallt anses kemiska begrepp med anknytning till materia och partikeltänkande vara svåra. Hanna beskriver detta nedan.

> Det jag kan tycka blir svårt med kemin, det är ju att förstå begreppen atomer och molekyler. Att det ska finnas atomer i det som vi ser. Man måste på något sätt påvisa att det finns atomer i den här vätskan, som vatten till exempel. (Hanna)

Enligt två andra lärare medför abstraktionen att elever, trots att de genomför en laboration har svårt att förstå eller inte alls förstår de kemiska processer de observerar. Det är inte självklart att laborationerna hjälper eleverna att koppla ihop teorin med praktiken.

> I och för sig händer det ju någonting men eleverna förstår inte vad som händer. Om man håller på med BTB och syror och baser till exempel, då testar man surt och basiskt och neutralt. Det är ju lite roligt, men om de egentligen förstår så mycket… inte just då i alla fall. (Diana)

Det är inte ovanligt att laborationerna i kemi blir mer styrda än i de andra ämnena, dels för att undvika risker och dels för att lärarna själva tycker att de vill ha kontroll på vad som kan hända.

> Det är väl mycket mer i kemin att eleverna får en instruktion. Där vill man inte att de ska prova sig fram alltför mycket, utan det är bra om det… man vill ju ha lite ordning och reda, för det kan ju hända grejer. (Magnus)

Ett par lärare uttrycker å andra sidan att oväntade överraskningar är en av fördelarna med laborationer i kemi eftersom eleverna blir mer intresserade och det ger upphov till en mängd nya frågeställningar som de kan undersöka vidare i nya laborationer.

Med laborationer i biologi är det lätt, liksom i fysik, att se anknytning till verkligheten omkring, men å andra sidan tenderar laborationerna i biologi att ta tid att genomföra. Eleverna uppskattar inte alltid det, eftersom de är vana vid snabba händelser i sin vardag.

> Jag tror att det är därför biologin blir lite eftersatt. Resten av samhället går snabbare och snabbare. Det tar för lång tid att sitta och titta när det växer, fast det är jätteintressant och fast många skulle behöva se och uppleva när det gror och växer. (Curt)

Tre av lärarna uttrycker att laborationer i biologi inte genomförs lika ofta som i kemi eller fysik. Till viss del beror det på att laborationerna anses ta lång tid, men det beror också på att det finns andra sätt att få kunskaper i ämnet.

> Jag tycker nog att jag jobbar bra med biologin, men inte så mycket praktiskt. Jag tycker det funkar att jobba på andra sätt… Visst tittar man på växter och sånt och vi tittar på inälvor från gris när vi jobbar med människan. Men i biologin är det mycket annat, som läsa och diskutera. (Berit)

Varje ämne har sina möjligheter. Med fysiklaborationer går det snabbt och enkelt att påvisa fenomen, laborationer i kemi kan överraska eleverna och i biologi hanterar laborationerna frågor som ligger nära sådant som eleverna kan associera till sin direkta omgivning.

Diskussion

Resultaten från denna studie visar att lärarna i stor utsträckning vill att det laborativa arbetet ska ge eleverna en ökad *förståelse* av naturvetenskapliga fenomen, fakta och begrepp. Till viss del beskrivs också att elever bör få *labvana* och bli *intresserade* av naturvetenskap. Lärarnas mål stämmer överens med de mål som både Jenkins (1999) och Wellington (1998) anser viktiga att eftersträva och med de mål som beskrivits av lärare i tidigare studier (Högström et al., 2006; Welzel et al., 1998). Denna studie visar att de svenska lärarna genomför laborationer där undersökande arbetssätt förekommer. De beskriver däremot inte att det medför att eleverna tränar kunskaper om hur man systematiskt undersöker fenomen i naturen, föreslår och testar hypoteser och underbygger påståenden genom belägg från resultat. Även de engelska lärarna i Abrahams och Millars (2008) studie genomför främst laborationer för att uppmärksamma det naturvetenskapliga innehållet och inte så mycket för att träna på naturvetenskapliga undersökningar.

Det finns ett ökat intresse för laborationer med ett undersökande arbetssätt inom NO-undervisningen (Hofstein & Lunetta, 2004). Det kan också ses i de rekommendationer för undervisning i naturvetenskap som presenterats av EU (2007) och Osborne och Dillon (2008). Användning av ett undersökande arbetssätt beskrivs av flera av lärarna i denna studie. Det är särskilt uttalat hos en lärare som vill att eleverna ska kunna planera och genomföra laborationer eftersom hon tycker att detta mål är klart uttalat i kursplanerna. Ett annat exempel, där ett undersökande arbetssätt används, är när lärarna använder enkla laborationer för att introducera elever till kunskapsområden som de inte arbetat med tidigare och för att ge eleverna inspiration till egna frågor och idéer. Detta gör att naturvetenskapliga idéer och elevernas egna frågeställningar och idéer i högre grad möts, vilket också förespråkas av Jenkins (2006).

Hofstein och Lunetta (2004) skriver att det är viktigt att laborationerna ger eleverna möjlighet att utveckla förståelse av naturvetenskapens karaktär. Även andra studier påpekar detta (Lunetta et al., 2007; Osborne et al., 2003; Schwartz et al., 2004). Schwartz et al. (2004) visar att det undersökande arbetssättet kan vara användbart för att utveckla elevers förståelse av naturvetenskapens karaktär om lärarna är tydliga med detta. När lärarna i denna studie talar om vad de vill uppnå, är naturvetenskapens karaktär nästan helt frånvarande. Endast en av lärarna nämner en laboration med anknytning till detta område. Ett par av lärarna talar om betydelsen av reflektion och diskussion i samband med laborationerna, något som kan leda till diskussioner om hur naturvetenskaplig kunskap uppkommer (Abd-El-Khalick et al., 2004). Våra resultat visar dock att naturvetenskapens karaktär i allmänhet inte anses vara ett mål för laborativt arbete. I en rapport från Skolverket (2007) redovisas att svenska 15-åringars resultat i PISA-undersökningen 2006 var under OECD-medelvärdet när det gällde aspekter som anknyter till naturvetenskapens karaktär och till naturvetenskapens användning, men över medelvärdet när det gäller begreppskunskap. Enligt rapporten, bekräftar detta att man i den svenska grundskolan i liten utsträckning undervisar om naturvetenskapens karaktär. Osborne et al. (2003) anser att undervisning om naturvetenskapens karaktär bäst görs genom ett antal väl valda fallstudier av antingen historiska eller samtida natur och genom explicit reflektion och diskussion om naturvetenskapen och dess natur. En möjlighet att hjälpa lärare att ta in aspekter av naturvetenskapens karaktär i samband med det laborativa arbetet skulle kunna vara att konstruera illustrativa exempel som ger tillfälle till reflektion och diskussion om hur den naturvetenskapliga kunskapen vuxit fram.

De svårigheter lärarna ser med det laborativa arbetet handlar om att få tillräckligt med tid för laborationerna, att hantera omgivande faktorer och att ge eleverna möjlighet att planera egna laborationer. Lärarna nämner till exempel att det kan råda brist på lokaler, att det saknas material till alla elever och att det är för få tillfällen med laborationer i halvklass. Lärarna tar främst upp sina svårigheter att genomföra laborationer och inte elevernas svårigheter att lära sig genom laborationerna. Flera lärare beskriver dock att den begränsade tiden för samtal med eleverna under laborationerna medför att det är svårt att hjälpa eleverna att koppla sina observationer till naturvetenskapliga idéer. Liknande resultat presenteras av Abrahams och Millar (2008). Enligt Kanari och Millar (2004) är det viktigt att lärarna kan hjälpa eleverna med vad som ska observeras och hur man gör. Detta är inte möjligt om det är för många elever i gruppen. Till exempel beskriver läraren Julia en laboration med mikroskopering i helklass, där risken är stor att eleverna bara ”sitter och tittar på luftbubblor”. Genomförandet är alltså i fokus, vilket även uppmärksammats i tidigare studier (Hodson, 1990; 1991; Hofstein & Lunetta, 2004; Millar et al., 2002).

De skillnader mellan ämnena som var mest slående var att fysiklaborationerna anses vara lättast att göra enkla och att anknyta till vardagen. Kemilaborationerna uppfattas som så abstrakta att eleverna inte förstår innehållet även om läraren hjälper dem med vad som ska observeras. Om eleverna genomför en laboration som handlar om atomer och molekyler innebär det inte automatiskt att eleverna förstår det lärarna vill att de ska förstå. Några lärare beskriver att de genomför färre laborationer i biologi än i övriga NO-ämnen. Det överensstämmer med resultat av Lindahl (2003), som visar att elever är osäkra om det över huvud taget genomförs laborationer i biologi. Även Abrahams och Millar (2008) anser att elever genomför färre laborationer i biologi. Våra resultat erbjuder två förklaringar till detta. Dels anser tre av lärarna att laborationerna tar lång tid att genomföra, vilket medför att eleverna lätt ledsnar. Dels beskriver en annan lärare att det finns andra sätt att lära sig biologi än genom laborationer, till exempel genom att läsa och diskutera. Josephsen (2003) visar att ett antal universitetsstudenters erfarenheter av att angripa problem och att tolka, diskutera och presentera data från laborativt arbete kan överföras mellan ämnen. Detta diskuteras inte av lärarna i denna studie. Resultaten indikerar, i likhet med studien av Abrahams och Millar (2008), att lärarna saknar en plan för att ta tillvara elevernas erfarenheter.

Alla lärare i denna studie uttrycker att det finns viktiga mål att uppnå med hjälp av det laborativa arbetet och att laborationer i de olika ämnena ger eleverna möjlighet att lära sig naturvetenskap, få labvana och bli intresserade. Laborativt arbete i grundskolans senare år ger eleverna vissa möjligheter till undersökande arbete. Däremot beskriver ingen av lärarna särskilda strategier för att träna dessa kunskaper och därför utnyttjas inte möjligheterna i så stor utsträckning. Ett annat viktigt resultat är att aspekter med anknytning till naturvetenskapens karaktär i stort sett inte alls finns med i de mål som beskrivs. Två frågor väcks utifrån detta resultat. Hur uppfattar lärare naturvetenskapens karaktär? Ska förståelse av naturvetenskapens karaktär innefattas i laborativt arbete eller är andra sätt att föredra?

Bilaga 1. Intervjuguide

Frågor om laborationer i undervisningen	**Semistrukturerat frågeinnehåll där läraren ombeds utveckla:**
1a. Vad innebär laborativt arbete för dig? 1b. Vad vill du uppnå?	– sin syn på innehåll, processer, färdigheter och olika arbetssätt – möjligheter som finns eller saknas – skillnader/likheter mellan biologi, fysik och kemi – med exempel ur undervisningen som kan förtydliga vad de avser
2a. Hur tycker du att du lyckas? 2b. Vad finns det för svårigheter?	
3. Hur kan elevers reflekterande kring det laborativa arbetet stimuleras?	

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Clas Olander works at the Department of Education, University of Gothenburg. Drawing on a background in teaching at several levels in secondary schools his current interest is the intersection of 'practice and theory'; especially students' language use when making sense of school science.

Åke Ingerman works at the Department of Education, University of Gothenburg. His research primarily takes its starting point in pedagogical situations where students meet scientific and technological knowledge in different forms, and aims towards developing the quality of that meeting.

CLAS OLANDER
University of Gothenburg
Sweden
clas.olander@gu.se

ÅKE INGERMAN
University of Gothenburg
Sweden
ake.ingerman@gu.se

Students' language use when talking about the evolution of life - negotiating the meaning of key terms and their semantic relationships

Abstract

In this paper, we explore an idea from Vygotsky about the meaning and sense of words, and how it manifests itself in students' talk. This is done by analysing the discussions of 15-year old Swedish students participating in teaching activities concerning biological evolution. It turned out that the students seldom articulated the scientific terms. Instead, they contextualised by using three strategies – paralleling, transferring, and delimiting. All three of these strategies have merits and drawbacks in connection with 'meaning' of single terms. However, when combining the terms into thematic patterns, the students formed rather sound and coherent scientific explanations. This is understood as relying on the students' use of an interlanguage where colloquial expressions serve as an asset in sense-making. The verbalisation of an explanation in an interlanguage is advantageous when communicating in social life outside the science classroom, and thus the possibility of further sense making is enhanced.

Introduction

Biological evolution could be explained, according to Stearns and Hoekstra (2000), by recognising three conditions: "individuals must vary in reproductive success; some variation in the trait must be heritable; the trait must be correlated with reproductive success" (p. 9). If the correlation between reproductive success and trait is either positive or negative, there will be natural selection (adaptive evolution); on the other hand, if the correlation is zero, there will be no selection at all (neutral selection). A similar way of expressing evolution accentuating the important terms is presented by Wallin (2004): "the theory of evolution can rather easily be described by using three concepts: existing variation, heritage, and natural selection" (p. 261). The definition articulated by

Stearns and Hoekstra resides directly in the science community, while the definition from Wallin is closer to school science.

One of the merits of scientific language is that the meaning of terms, concepts, models, and theories are well defined and specified in the scientific community. When entering school science, these terms, concepts, models, and theories are often expressed with simplifications and delimitations. One of the challenges for school science is to explain science without sacrificing the essence of the language in science. Accordingly, exploring the meaning that students make of the scientific terms would be a way to increase understanding of the relations between science and school science, as well as between colloquial and scientific language. In this paper, this is done with reference to the distinction Vygotsky (1986) made between *meaning* and *sense* of expressions. Meaning is the stable (generalised, collective and lexical meaning) zone of an expression, while sense is more situated and dependent on the context of the talk (personal, local and creative meaning).

Learning science involves making sense of the school science language, which, according to Reveles and Brown (2008), includes the ability to contextually shift between different social languages (Bakhtin; 1981), in this case, the colloquial and scientific languages. The ability to use, translate and distinguish between social languages is one of the aims of science education and the more confidently the students move between languages the more mature is their understanding (Mortimer & Scott, 2003). When students work with making sense of the scientific language, through the use of colloquial language, they may develop a new hybrid language; an *interlanguage* (Barnett, 1992; Lemke, 1990). This interlanguage is more personal and dynamic (Gomez, 2007) and the possibility of connecting and bridging between informal and formal accounts of phenomena increases (Brown & Spang, 2008). This mixture of two social languages is used analytically in science education research when, for example, examining teaching and learning about biological adaptation (Ash, 2008) and teaching and learning about evaporation, boiling and condensation (Varelas, Pappas & Rife, 2006).

Explaining biological evolution may appear straightforward in the science community, but it is a topic that educational research has depicted as challenging for students to make sense of; the process of sense-making, in general, is assumed by Bruner (1985) to consist of conceptual, epistemological and ontological aspects. The most prevalent ontological aspects are related issues that shape our world views: for example, religion, gender, ethnicity, and ideology (cf. Cobern, 2000; Smith & Siegel, 2004). The epistemological issues that are most challenging deal with formation of explanations, for example, choosing a teleological or a causal explanation (Kampourakis & Zogza, 2008; Mayr, 2004), or the choice of biological organisation level when explaining (cf. BSCS, 1993; Zetterqvist, 1995). Examples of conceptual aspects are those mentioned above: variation, heredity, and selection (cf. Ferrari & Chi, 1998; Wallin, 2004), and also, for example, individual or population focus (Greene, 1994) or geological time (Dodick & Orion, 2003).

This paper reports an analysis of students' talk in peer group discussions in a Swedish compulsory school, a pedagogical context where activities were informed by insights from a didactical analysis of relevant scientific terms for explaining biological evolution; according to Brown and Ryoo (2008) it is the combination of conceptual and language components that enhances students' understanding of phenomena. The aim of this paper is to explore in what ways the terms serve as tools in the students' talk and in what ways the meanings of the terms are articulated. The specific research questions focus on students' use of the key terms (variation, heredity, and selection) that the teacher intended to communicate the scientific story with. Firstly, the analysis focuses the terms one by one, and secondly, it focuses on the linking between terms when construing explanations of biological evolution. Thus, the specific research questions are:

- In what ways are meanings of the key terms construed in the students' discussion?
- In what ways are key terms linked to explanations in the students' discussion?

Methods

Data collection and context

The data analysed in this paper were generated within a teaching intervention with the aim of introducing the theory of evolution as a tool for reasoning, referring to the key terms *variation, heredity, and selection*. The teaching strategy was to include many opportunities for students to explore their understanding of ideas; ideas that were introduced both by the teacher and the students. The teachers often enacted the teaching strategy as activities that included talk in peer groups, and in order to explore the students' sense-making of the key terms, recordings of students' discussions in peer groups were made, activities that were an integrated part of regular teaching. The students were approximately 15 years old and all in grade 9, which is the last year of compulsory schooling in Sweden.

Altogether 19 students in 7 groups were recorded while performing two types of activities, both of which were supposed to enhance the students' use of the theory of evolution as a tool for reasoning, and specifically the terms variation, heredity, and selection. The students' talk analysed relates to the following two activities (performed during lesson number five and six of totally nine lessons):
– discussing while working with an interactive web-based application (*predict population*)
– discussing the result of a hands-on game where students acted as predators (*selection game*).

In the web-based activity (*predict population*), pairs of students worked with an activity developed by Wallin and Andersson (2004). On the screen, the students were given written information, which they discussed and then sent a written response to a database; the database generated new information, students talked, sent new responses, etc. The analysis was performed with respect to two parts of the activity, where the first part was students' talk when they discussed the information that introduced the activity. The text on the web page was:

> During a period of a couple of days a population of reindeers was observed by a scientist. She noticed a great variation in the length of the reindeer's legs. The scientist divided the population into three groups with respect to length of legs. She saw that 20% had short legs, 60% had somewhat longer legs, and 20% had long legs.
>
> Let us now imagine that you are visiting this population of reindeers in the same area many reindeer generations later. Use what you have learnt about the theory of evolution, and speculate about the length of legs of the reindeers at this later time.

After submitting their answer to the database, the students were given new information and were asked whether they wanted to alter their previous prediction. For example, the students were informed that a population of wolves lived in the same area, and that it was easier for these wolves to hunt short-legged reindeers than the more long-legged ones. The consequences for the wolf population (of differential prey population) are the second part that is analysed. Totally, ten pairs of students carried out the activity, and five of these pairs were audio recorded when talking.

In the *selection game*, students in groups of four/five played the role of predators and tried to catch prey on a playing board. The game resembles an activity described by Stebbins and Allen (1975); however, in the version used here, the prey population consisted of paperclips in ten different colours; ten of each colour (totally one hundred clips) were spread out on a playing board. The differently coloured clips were supposed to represent a variable population of preys. Now the game started and in the first round the students picked (hunted) the clips by sight; they picked up one by one while walking around the playing board until there were twenty-five clips left. Then the clips 'reproduced', meaning that for every clip that was left on the board three more were added, thus the clip population was again one hundred individuals. Now a new round (hunting season) began and this could go on for three or four rounds (seasons). The students then sat down and tried to explain that result, for example, the distribution among the colours had changed, and there were not ten of each anymore. Some colours could be very frequent while other colours were not even present at all. The whole game with two groups were video recorded although the analysis mainly focuses on the concluding talk between students, approximately ten minutes from each of the two groups; totally nine students.

Analytical procedure

It was soon obvious that the students seldom explicitly verbalised the key terms *variation, heredity, and selection*; instead, they made several reformulations. Consequently, the interest turned towards these reformulations and the emerging structures of how the students addressed the key terms linguistically. When generating structuring tools, our first source of inspiration was Vygotsky's (1986) distinction between *meaning* and *sense* of a word. However, in this paper the 'words' we focus on (variation, heredity, and selection) have a specific use and conceptual bearing; hence, we depict them as terms. In the introduction, we referred to meaning as the stable and generalised zone of a term, while sense is more situated and dependent on the context. In this paper, our assumption is that the use of the terms in the science community is closer to the generalized meaning, and in the students' talk it is mainly the locally and situated sense that is focused on.

Analysis of the ways meanings of the key terms are construed in the students' discussion

The analytical focus has been on students' talk, instances where the students' contextualise the key terms. The function (sense) of the contextualisation, in the students' talk, in relation to generalised and collective meaning in this way becomes our main interest. For example, the students never uttered the term variation, instead they talked about differences. Likewise, they never explicitly mentioned selection and instead they talked about the consequences of how well animals 'managed' or differential rates of survival and/or reproduction. The analysis of students' talk identified and made tentative use of three strategies of sense-making (see Table 1), strategies that served as conceptual links in the students' talk, which we labelled: *paralleling*, *transferring*, and *delimiting.*

Reformulations with *paralleling* or using synonyms are made, according to Brown and Ryoo (2008), when a term (often scientific or technical) is somehow uncomfortable, partly unknown, or difficult to pronounce. A more familiar parallel word residing in everyday settings is used instead, which in turn could lead to other interpretations than were originally intended. For example, the term 'autotrophic' used in biology as science, becomes 'producer' in school science; whereas 'those that make their own food' would be a parallel in colloquial language.

When *transferring,* the unknown is connected to the known by using metaphorical expressions. The rationale is to make links in the sense of 'understanding and experiencing one kind of thing in terms of another' (Lakoff & Johnsson, 1980, p.5). When explaining something 'in terms of' (using a metaphor), it may imply other interpretations and thus have educational implications (Pramling,

Table 1. *The three strategies' relation in context, meaning, and sense.*

Strategy	Context (relation to the task)	Meaning (generalized meaning)	Sense (function in the talk)
Paralleling	Same	Potentially same	In the students' talk it is meant to be the same; thus, the point of departure in the analysis
Transferring	Different	Uncertain	
Delimiting	Different	Partly different	

2008). Transferring could be done using anthropomorphic metaphors, for example, like Darwin did with 'struggle for existence'; another example of Darwin's transferring strategies is the comparison between *artificial* and *natural* selection.

Delimiting the meaning is done when a term could be interpreted broadly and with different specificity and quality. Often, delimiting is done as a specification when a term has different interpretations in informal/colloquial and formal/scientific contexts. For example, when explaining biological evolution the term *adaptation* is often used (cf. Kampourakis & Zogza, 2008), in this case, a specification is essential. On other occasions, delimitation can curtail the meaning of a term, it loses nuances or even essential aspects of its meaning.

Analysis of the ways key terms are linked to explanations in the students' discussion

The second research question deals with the students' generation of explanations or, more precisely, the students' use of the key terms (sense of the key terms) in relation to each other. This linking of key terms results in a network of semantic relationships between terms, which, according to Lemke (1990), is a thematic pattern that describes the science content. Thereby, the unit of analysis changes; in relation to the first question, attention was focused on contextualisation's of single terms, while in the case of this second question, attention is focused on longer sequences of students' talk concerning negotiations of possible ways of explaining the given tasks. The two prevalent ways in which the students' negotiated explanations constituted on the one hand *discernment of differences* between terms and on the other, *linking and coherence* between terms. In both cases (discernment of differences and linking), it was also possible to explore different qualities in the students' ways of explaining.

When explaining biological evolution, a qualitatively rich answer should include, according to Ferrari and Chi (1998), five terms or components: *individual variation, heredity, differential survival, differential reproduction, and accumulation of changes*. The three latter components together frame the notion of selection; however, taken separately they could point to different understandings. Differential survival is merely a step towards the most crucial component, which is differential reproduction. The component of accumulation, which can be seen as the result of repeated selection points to a definition of evolution as the *change of gene frequencies in populations*. In this statement, selection refers to the organisation level of populations although the level of molecule (gene) is present. However, it is individuals that reproduce; hence, quality in explanations could be explored depending on the organisation levels that are used. The estimation of quality relies on the linking and relations of the components, for example, if they are articulated with a causal manner.

Findings

In this first section, the students' sense-making of the three key terms (variation, heredity, and selection) is analysed in relation to three identified strategies: paralleling, transferring, and delimiting. The general patterns that were outlined in Table 1 are specified and exemplified in Table 2. Furthermore, it should be noted that the exemplifications in Table 2 are a summary of the findings presented in connection with excerpts 1 – 10. For example, when variation (i.e. Vygotsky's meaning) is reformulated as difference (i.e. Vygotsky's sense), this is taken as an example of paralleling (excerpt 1; turn 96: `they haven't got a mutation ... it is only that they are differently tall we are different as well)`. In relation to the task, this reformulation is rather appropriate, hence paralleling. However, in relation to a generalised meaning, it is vague since difference could be understood on different organisation levels; for example, in excerpt 1 the students discuss whether the origin of the difference should be understood on the level of gene or organism.

Table 2. *Examples of the students' sense-making of the key terms. Please note that the sense of the terms (their function in the talk) is seemingly the same, judged by the conversation.*

Strategy	**Example (from excerpt 1 - 10)**	**Context (relation to the task)**	**Meaning (generalized meaning)**
Paralleling	Variation → difference (cf. excerpt 1; turn 96)	Same; refers to diversity in traits (length of legs and colour, respectively)	Potentially same; difference could be understood on varying organisation levels
	Heredity → disposition lives/carried on (cf. excerpt 2; turn 67)	Same; together, the words place disposition close to the term heredity	Potentially the same; refers (only) to the passive transport of genetic information
Transferring	Selection → manage (cf. excerpt 6; turn 440)	Different; manage could imply survival but not reproduction and accumulation	Uncertain; vague in relation to explanations in biology
	Heredity → lives/ carried on (cf. excerpt 8; turn 114)	Different; heredity is a process that shapes both similarity and dissimilarity	Uncertain; whether it points to shaping similarity or dissimilarity
Delimiting	Heredity → disposition (cf. excerpt 2; turn 65)	Different; since vague and ambiguous, it has to be contextualised	Partly different; there are (at least) five connotations of the word disposition
	Selection → survive, reproduce, and/or accumulate (cf. excerpt 8; turn 114/6)	Different; the model was supposed to include all three components	Partly different; choice of component(s) alters understanding

Contextualisation of variation

The term variation is written at the beginning of the text in the computer activity and in the selection game, the students are told that the paper clips varied in colour; yet the term variation is never explicitly used by the students. Instead the students talk about *differences*, which is a reformulation with a parallel word. In excerpt 1, based on computer activity, the students should speculate on whether a change over time has taken place. The students in this context interpret variation as differences, and they take change (difference over time) as their starting point; change is taken for granted.

Excerpt 1

89 Eva: first of all, it is a mutation that makes you get longer legs

90 Emma: mm

91	Eva:	`and since they would rather take your friend who doesn't have your mutation`
92	Emma:	`mm`
93	Eva:	`because they get hold of your friend more easily therefore you survive and your children get your dominant mutation`
94	Emma:	`mm`
95	Eva:	`the reindeers that survive are those who got the mutation`
96	Emma:	`they haven't got a mutation ... it is just that they are different heights we are different as well`
97	Eva:	`there is a reason why we are different`
98	Emma:	`so Miranda has a mutation since she is taller than us`
99	Eva:	`no, but that is what has happened`
100	Emma:	`no, her parents are tall`
101	Eva:	`it must have been a mutation that made` (predict population, group 3)

In the excerpt above, the origin of the difference (variation) is negotiated, starting out with a claim from Eva: `first of all, it is a mutation that makes you get longer legs` (turn 89): this reference to genetic reasons is in line with the school science view. However, Emma in turn 96 changes Eva's general reasoning about the origin of change into a more personal and local context `we are different as well;` exemplified with reference to a mutual class mate: `so Miranda has a mutation since she is taller than us` (turn 98). This could be seen as a negotiation on how to contextualise the explanation. Eva argues for the *ultimate* origin of variation when she claims `there is a reason that we are different` with reference to mutations. Emma finds it odd that mutations should explain the height of a mutual friend and goes for the more colloquial and *immediate* explanation `her parents are tall` (turn 100). The negotiation is somehow settled when they write the text in the database where they do not mention any genetic reasons for differences in the length of legs; they only claim that that there is a difference in the length of legs and that this difference has consequences. These consequences will be further elaborated when research question two is discussed (excerpt 8 9 and 10).

Contextualisation of heredity

The excerpt below is from the first part of the computer activity where the students are supposed to speculate about possible change in length of legs among reindeers. All three sense-making strategies are used by the students.

Excerpt 2

61	Gail:	`disposition ... gets most of the times the disposition`
62	Gro:	`no but hello`
63	Gail:	`they can only`
64	Gro:	`it doesn't matter a damn`
65	Gail:	`disposition for long legs ... and in that way it lives on (`*silence for 20 seconds while Gail writes*`) ... those with short legs don't survive and their disposition isn't carried on ... their sets of genes`
66	Gro:	`disposition was good`
67	Gail:	`disposition isn't carried on, stop` (predict population, group 5)

Here, heredity is first reformulated into disposition as almost a word *parallel*. However, disposition is, in turn, reformulated as something that `lives on` or `isn't carried on` (turn 65 and 67). Expressed in this *transferred* way, heredity reflects a view of passive transport of particles, which is a *delimitation* of the 'original' term heredity.

The expressions *lived* or *carried on* are metaphorical (transferred) in the sense that instead of saying inherited, the students reformulate to 'in terms of'. In this case, (in terms of) something that lives or carries on implies stability and similarity, thus the transferred sense points to the passive part of heredity, the process that causes similarity between generations (passive transport of the DNA in the gamete during fertilisation). The active process (mutations), which causes dissimilarity between generations, is thus toned down.

Furthermore, the synonymous term disposition has wider connotations, mainly in colloquial language. Consequently, the conversation in turns 65 - 67 is also a negotiation of delimitations, about how to understand what it is that actually is 'carried/lives on'. The students' label is *disposition;* in Swedish, the students' use the word 'anlag', which could be understood in various ways. In general and broad use, disposition could imply *tendency*, for example, 'tendency to put on weight' or it could refer to *talent*, for example, 'have a talent for football'. In a biology context, disposition could be a first stage or trace, *rudiment*, for example, 'rudiment of feathers' or it could refer to an *ability* (trait), for example, implying the ability to swim. However, the most frequent use in science settings is *hereditary disposition*, implying 'set of genes'. In this excerpt, the pair of students agree on the broader wording (turn 67), but the reference to 'genes' in turn 65 implies that their interpretation is close to the scientific notion.

Contextualisation of selection

The term selection is not explicitly used; instead, ways of understanding the term selection are negotiated by means of *delimitations*. Typically, students make delimitations by focusing on different components: survival, reproduction, or accumulation (cf. excerpt 3 and 8), which could be inherent in the term selection (Ferrari & Chi, 1998).

Excerpt 3

84	Eva:	`first I thought that it was like mutations and that is, of course, true, but then it is definitely also like this ... that it is those with longer legs that survive better and then it is those who reproduce`
85	Emma:	`exactly, then we write like this ... let us take the example that all reindeers are chased by wolves ... the fastest survives`
86	Eva:	`which is the one with the longest legs`
87	Emma:	`because it runs fastest, has a good mutation` (predict population, group 3)

If the survival component is distinguished, with the aspect of differential survival, then differential reproduction rate could more easily be explicitly mentioned as a consequence: `those with longer legs survive better and then it is those who reproduce` (turn 84). The discussion could also lead a few steps further as will be shown later (excerpt 8) where the students stretch the term selection to include several generations and an increase in the frequency of the gene (trait) – an example of linking to the component accumulation.

In the selection game, the students were faced with explaining change in frequencies of colour distribution among the paper clips; some colours became more frequent while other became less so. In excerpt 4, the discussion aims at explaining why there are so many light blue clips left.

Excerpt 4

222	Andy:	`they taste yucky`
223	Alice:	`they are faster`
224	Andy:	`they are stronger`

225	Anna:	they are more pleasant to the eye
226	Agnes:	they are visible in relation to the background
227	Alex:	I think that
228	Anna:	then they should be gone
229	Agnes:	the black ones are not gone I can't take it anymore
230	Andy:	the blue ones have a small extra defence like a small spike
231	Anna:	I think that the blue colour makes them poisonous like that Pilgrim frog, they have are so strongly coloured that you iujj
232	Alice:	same thing with the red, they can be red by such mystic
233	Anna:	look, there are only bright colours left
234	Agnes:	look, here is one that shines and there is one that doesn't
235	Anna:	which is more pleasant to the eye (selection game, group 1)

The members of the group bring up several examples of the frequent occurrence of light blue clips: `they taste yucky, are faster or stronger, have a small extra defence;` thus students talk about clips as eatable prey and they *delimit* the term selection to survival. All the explanations above could be regarded as a result of the students' ability to engage in the game and it is firmly situated in the context of the actual game. At one point (turn 231), there is a reference that stretches outside the actual game when Anna refers to aposematism[1] with the claim `I think that the blue colour makes them poisonous like that Pilgrim frog` and turn 233 `there are only bright colours left`. This seems plausible to Agnes since `look, here is one that shines and there is one that doesn't shine` (turn 234) thus taking the conversation back to the actual game. The inputs from Andy/Anna in turn 230/231 are intended to respond to the remark by Agnes in turn 226, which contradicts the 'best camouflaged explanation'. The same kind of explanation is also what the other videotaped group starts out with:

Excerpt 5

440	Bob:	if we were to do it again, the orange would not manage
441	Bea:	I think it has to do with which, you see it depends on the background, it is the same thing as environment
442	Bree:	but if you take randomly it would not be like that ... Boris chose to take the black ones
443	Bob:	if you keep your eyes closed
444	Bea:	yes but if we think of it as an environment, like the savannah and then these, like, yellow-orange will... then it is better to be than like black you are more visible if you are black than if you are yellow-orange
445	Bob:	but in this game it was better to be black
446	Bea:	yes it was (selection game, group 2)

Here, the conversations stretch outside the specific game, when Bea makes a *parallel* between environment and background: `it depends on the background it is the same thing as environment /.../ on the savannah you are more visible if you are black than if you are yellow-orange`. Bob seems to agree with these claims, and refers to the actual game they were playing: `but in this game it was better to be black`. Such connections between the actual game and the natural world are rare in this study.

Semantic relationships between key terms in the students' discussion

First, two excerpts are given where students discern significant differences between the key terms, and by doing this they generate explanations. Examples will be given where students make coherent use of the key terms, or more precisely their sense of the key terms, as tools in order to generate explanations.

Discerning differences between key terms

In this section, the focus is on instances in the students' talk where they negotiate delicate but important nuances (differences) in wording connected to understanding *variation and selection*. Furthermore, in the students' talk there are alterations and translations between different social languages.

Excerpt 6

50	Gro:	those reindeers with
51	Gail:	intermediate length of legs
52	Gro:	yes, longer legs
53	Gail:	find it easier to escape and their generations, or find it easier to escape because they then become faster
54	Gro:	it is rather obvious but ok ... should I write become or are
55	Gail:	they are
56	Gro:	and wait ... get children
57	Gail:	manage ... and survive
58	Gro:	and survive ... their children get
59	Gail:	get
60	Gro:	get the same opportunities (predict population, group 5)

Excerpt 7

70	Eva:	the development could have meant several things ... that the wolves got a better sense of smell ... or that the wolves who had a good sense of smell survived
71	Emma:	because they could find more animals and see enemies from long distances
72	Eva:	those wolves with, for example, a good sense of smell survived, 'cos they could sense the smell of prey (predict population, group 3)

In excerpt 6, the students negotiated the importance of distinguishing between the words *are* and *become* (turn 54, `should I write become or are`), which relates to paying attention to the existing variation (`are`) in the population versus what this variation could lead to (`become`). Excerpt 7 makes the same aspect visible (turn 70, `the wolves got a better sense of smell ... or that the wolves who had a good sense of smell`), that is the difference between whether the wolves already *had* different abilities or if it was a result of selection (*got* better). In both excerpts, the students agree on a formulation that points to an explanation that draws on the existing variation. Furthermore, it is interesting that they, on the whole, stress the importance of the point. The existing variation was implicitly formulated in the information the students read, for example, potential difference in the length of legs of reindeers and the potential hunting success of wolves. Still, the students found it important to discuss the significance of this information as they formulated their own answers, answers that are neither in scientific nor colloquial language, but something in between, an interlanguage.

Linking and coherence when generating explanations

A main feature is that the generalised meaning of the term selection is only articulated if the existing variation is articulated or somehow taken for granted. In the computer-based activity, variation between populations is implied in the task, which the students discern, and in most of the discussions the term variation is taken as a point of departure. The students proceed rather directly with what the variation (difference) could lead to, thus articulating the meaning of selection.

The first excerpt in this section brings up all five components (individual variation, heredity, differential survival, differential reproduction, and accumulation) that Ferrari and Chi (1998) conclude should be part of an evolutionary explanation. However, it is done without explicit wording of the components.

Excerpt 8

110	Fia:	`those reindeers with longer legs could maybe run faster than those with short legs and then escape predators easier`
111	Fiona:	`lynxes ... lynxes`
112	Fia:	`lynxes and tigers and`
113	Fiona:	`wolves`
114	Fia:	`right wolves ... ok and then they survive and carry their genes on to their children who also get longer legs`
115	Fiona:	`yes`
116	Fia:	`and then they survive too and after many generations since it is a problem it turns out that many get longer legs`
117	Fiona:	`yes` (predict population, group 4)

The existing variation (some reindeers have longer legs) is taken as a point of departure and this variation has consequences when the reindeers are hunted; thus bringing the notion of *selection pressure* into the explanation; however, it is expressed in interlanguage: `since it is a problem it turns out`. One consequence is survival, a component of selection, `then they survive`. Heredity is rather weakly linked to the explanation of the origin of variation, but the term heredity is brought in with `carry their genes on to their children` (carry used as *transferred* sense of inheriting). This is also the part that points to the role of reproduction in the selection process. The component of accumulation is pointed out by mentioning that selection is repeated and takes many generations.

In the excerpts presented so far, the students mainly talk about natural selection, which was the intended focus in the teaching-learning sequence. However, when Fia and Fiona go on talking (see below), they raise another aspect of selection, sexual selection.

Excerpt 9

125	Fia:	`maybe they are also better looking`
126	Fiona:	`maybe they are ... write it down`
127	Fia:	`they are probably also sexier`
128	Fiona:	`please be more professional (`*`giggles`*`)`
129	Fia:	`(`*`writes`*`) more aesthetically pleasing` (predict population, group 4)

This discussion also points to the fact that the students seem aware of the existence of a certain way of expressing oneself in school science; thus pointing to the awareness of different social languages. The conversation about reindeers is first articulated in colloquial language, influenced by anthropomorphism. However, the colloquial words `better looking` and *`sexier`* are not assumed by the students themselves to be sufficiently correct. Furthermore, the words locally are situated exemplifications, which are in contrast to the more generalised expressions in school science. When submitting to the database, the words `better looking` and `sexier` are replaced by the synonymous `aesthetically pleasing`, – a sign of the students' view of the accepted formal school science language.

The last excerpt is an example of the generation of a causal explanation in the students' own choice of words. Furthermore, it is an example of how the students co-construct explanations.

Excerpt 10 (which is partly a fusion of excerpt 1 and 3)

84	Emma:	`I first thought that it was like mutations and that was surely true as well, but then it was also like this ... that those with longer legs survived better and then it was those who reproduced`
85	Eva:	`exactly, then we write like this ... let us take the example that all reindeers are chased by wolves ... the fastest survives`
86	Emma:	`which is the one with longest legs`
87	Eva:	`because it runs fastest, has a good mutation`
88	Emma:	`well`
89	Eva:	`first of all, it is a mutation that makes you get longer legs`
90	Emma:	`mm`
91	Eva:	`and since they would rather take your friend who doesn't have your mutation`
92	Emma:	`mm`
93	Eva:	`because they more easily get hold of your friend therefore you survive and your children get your dominant mutation` (predict population, group 3)

Emma mentions the aspect of heredity at the beginning (technical term `mutations`), and so does Eva both in the middle (technical term `mutations`), and at the end (`your children get your dominant mutation`). Variation is discerned (some had `longer legs`). This variation faces the environment (`all reindeers are chased by wolves`), thus resulting in selection (`the fastest survives`). When introducing the wolves in this example, the students touch upon the notion of *selection pressure*. The result of this pressure on the population of reindeers (hunting wolves) is formulated by Eva using interlanguage: `would rather take your friend who doesn't have your mutation /…/ more easily get hold of your friend therefore you survive.`

Discussion and implications

The students' reformulations of the key terms are made in an interlanguge (Ash, 2008; Lemke, 1990) that borrows characteristics from two social languages: the colloquial and the school science languages. In this way, the students' talk is framed in a kind of hybrid language with translations between the different social languages and different interpretations of the terms are negotiated. The relations, and their significance for learning, between the use of single terms and these terms combined into coherent explanations such as the theory of evolution, are expressed by Lemke (1990) as: "the systems of related meanings that constitute a scientific theory are learned and used primarily through language and correspond to a thematic pattern of thematic items (key terms, or 'concept words') and their semantic relations to one and another" (p. 121). We will discuss two possible consequences of the students' different linguistic usage; first in relation to the quality of reasoning and then in relation to the students' learning.

The quality of the formulation and reformulation of terms is understood here in relation to the *meaning* of the term; what Vygotsky (1986) referred to as a word's collective, generalised, and lexical meaning. This is, in turn, connected to the learning goal in formal schooling, which, according to Vygotsky (1978): "is concerned with the assimilation of the fundamentals of scientific knowledge" (p. 84). As we have shown, the students express themselves in an interlanguage and the terms are contextualised with paralleling, delimiting and transferring strategies.

Taken individually, these contextualisation strategies tend to lack precision and often the quality is reduced and diluted in relation to the collective *meaning* of each term; for example, the term selection is delimited to one component: survival. However, looking at full explanations, the pattern is partly different; then the students are able to present rather coherent and scientifically sound explanations. For example, the students often include the necessary components of an evolutionary explanation (Ferrari & Chi, 1998) and they link these components in a coherent and causal manner. This conclusion is in line with Lemke's (1990) remark: "the meaning of the whole is more than the sum of the parts" (p. 12). This is most prevalent when students perform the population prediction activity, maybe due to the fact that the instructions on the screen explicitly pointed to the intraspecific variation (Wallin & Andersson, 2005). Likewise, in the selection game the intraspecific variation was also explicitly given, but in an oral form, although the students did not present coherent evolutionary explanations.

The students were part of a teaching intervention with the aim of focusing on the theory of evolution as a tool for reasoning, referring to specific terms. A rather promising evaluation of the students' learning outcome has been made elsewhere (Olander, 2009) based on an account of written answers three months after the teaching ended. For example, the students who participated in the intervention answered significantly more in line with a scientific view than a comparable national sample did. This development in reasoning could potentially be explained by the students' emerging use of interlanguge. Articulations in an interlanguage manner relate probably more to everyday experiences (than school science language) and might be easier to externalise in everyday situations and thus be elaborated and refined, even after and outside teaching in classrooms. Connecting school and everyday knowledge is epistemologically important when learning physics, according to Hammer and Elby (2003), and when learning biology (Brown & Ryoo, 2008; Ash, 2008).

Our choice of analysing students' talk when they participate in activities is inspired by the idea that no activity can speak for itself (Bergqvist, 1990), and the assumption that it is in the talk around the activities, not the activities as such, that learning can occur (Mortimer & Scott, 2003). However, the rationale when designing activities in pedagogical settings influences and frames the way the activities are received by the students. First, we will outline some differences between the use of *models* in science and school science and then discuss the rationale for the activities used in this study.

In science, models and modelling are used in order to describe and frame a specific part of the natural world; the purpose is mainly to make predictions and concordance with the natural world is the measure of quality. In school science, models and modelling are (delimited) versions of science, used mainly in order to describe and visualise scientific methods and the products of science. In the classroom, for example, methods and historically important experiments/detections could be demonstrated through laboratory work and concepts, models, and theories could be used as 'scripts' when designing student activities. The purpose is pedagogical, and clarity of explanation power is the measure of quality.

The activities focused on in this study, predict population and selection game, were framed as generalised descriptions (models) of the theory of evolution; which as scripts served a purpose in the school science version of the theory, referring to the terms variation, heredity, and selection. The similar features of the two activities were a focus on one typical trait (length of legs and colour, respectively) within a population, along with pointers towards change over time and generations. Both activities involved prey/predator as theme, however, in the selection game prey/predator (paper clips and students) were part of the initial rules. In contrast, in the predict population activity the prey-aspect was introduced first and predators later on (however, many students referred to predators almost immediately). Nevertheless, the aspiration with modelling, whether it concerns scientific prediction or pedagogical clarity, is the possibility of making connections to 'the world'. The findings of this study are that there are rather few occasions when the students connect the actual activity with the world outside.

What are the implications of the fact that the students do not verbally articulate the key terms? After all, we have shown that the terms have specific meanings and enhance comprehensible communication, at least when used inside the scientific community. From a school science perspective, the reformulations *decrease the precision* momentarily, but not necessarily in the long run, because it is part of the process of sense-making. It could cause problems for those students who choose science for further study and a career. However, if they have grasped the *meaning* of the terms it would be fairly easy to 'copy' the accurate terms for the phenomena; the meaning of the term in that specific scientific community (cf. Brown & Ryoo, 2008). The reformulations *increase the relevance*, in the sense that the verbalisation of an explanation in an interlanguage is advantageous when communicating in social life outside the science classroom and thus the possibility of further sense-making is enhanced; an ongoing sense-making process that Hammer and Elby (2003) describe as "reconstructing and refining one's current understanding" (p.54). Moreover, being comprehensible without flawing the scientific meaning is a rare ability – perhaps interlanguage is the key.

Notes

1. Aposematism is (a defence mechanism) when an organism has a colour that resembles a poisonous species, for example, the poison dart frog (*Dendrobates tinctorius*), which probably is the frog that Anna is referring to.

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