Thesis for the degree of Doctor of Philosophy in Natural Sciences,
specializing in Education

A landscape of values

A study of non-epistemic values in Swedish upper secondary science education

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Cover: Ida Nordqvist taking a walk in the woods, valuing the wonders of nature.

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Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less.

Marie Skłodowska-Curie
(1867-1934)

English abstract:

This thesis sets out to investigate the role of non-epistemic values in science education from three actors' perspectives – the science student, the science teacher, and the science teacher educator. More specifically, the focus is on exploring the variation of values among these three key actors in science education, and what characterizes these values. Also, to use the empirical findings to discuss how these values (may) affect and inform science education research. Previous work on values in science education has failed to address the role of different actors in one specific educational context, which this thesis aims to achieve by studying the upper secondary school science education. In addition, values held by university scientists teaching science student teachers seem to be missing in previous research in the domain. In order to tackle the research questions, empirics were collected from all three actors targeted, in one specified science education context, and then use viable analytical methods and tools to describe the variation, character, and nuances of values held by the actors. To empirically investigate the variation and character of these values, an analysis was performed by a systematic literature review of the research domain. This was followed by surveying and statistically analyzing responses from representative samples of Swedish upper secondary school biology students and teachers respectively, and finally thematically analyzing interviews with university biology scientists in education of science teachers. Results showed that values held by science students and science teachers affect science education in schools. For example, teachers' non-epistemic values affect the content and methods selected and implemented in their science teaching. Further, it was found that the interviewed science teacher educators considered their teaching offered to science student teachers as largely value-free, while they acknowledged that values-inclusion in school science is something important. The key impact of the research presented, is that continued development of the growing research domain of the importance of values in science education is crucial, as there are many aspects in the domain not yet or thoroughly explored. Examples include the role of scientists in science teacher education, and how values held by science teachers affect their classroom practice. By incorporating findings from this study into the larger research discourse on values in science education, there is promise that research is one small step closer to suggest changes in curriculum and classroom practice. This could in turn change the current negative trend in student interest and motivation to study school science.

Svensk sammanfattning:

Denna avhandling syftar till att undersöka rollen som icke-epistemiska värderingar inom naturvetenskaplig utbildning i skolan spelar, sett ur tre naturvetenskapliga aktörers perspektiv: elevens, lärarens respektive ämneslärarutbildarens. Mer specifikt undersöks hur värderingarna kan karaktäriseras och hur variationen av värderingar som uttrycks hos de tre nyckelaktörerna ser ut. Tidigare forskning kring värderingar i skolans värld har inte lyckats klargöra dessa aktörers roller inom en och samma skolkontext på det sätt som görs i denna avhandling. Det saknas även forskning kring vilka värderingar naturvetenskapliga forskare har och hur dessa påverkar deras undervisning av lärarstudenter. Ett viktigt syfte är därför att med de empiriska resultaten som bas, bidra till forskningen kring värderingars betydelse för undervisning i naturvetenskapliga ämnen och att diskutera hur den negativa trend som länge har kunnat ses kring elevers intresse och motivation att studera naturvetenskap i skolan eventuellt kan förändras. För att besvara forskningsfrågorna samlades empiri från alla tre aktörer in, från en och samma naturvetenskapliga utbildningskontext. Med hjälp av ändamålsenliga verktyg och analysmetoder har variationer, karakteristika och nyanser hos elevernas, lärarnas respektive ämneslärarutbildarnas icke-epistemiska värderingar i förhållande till naturvetenskaplig utbildning undersökts. I ett första steg genomfördes en systematisk litteraturöversikt inom forskningsområdet. Sedan följde en enkätstudie med statistisk analys från ett representativt urval av svenska gymnasieelever respektive lärare i biologi. Till sist genomfördes tematiska analyser av intervjutranskript från intervjuer med forskande biologer som undervisar lärarstudenter i biologi på universitet. Resultaten visar att de värderingar som elever respektive lärare i naturvetenskap uppvisar verkar påverka den naturvetenskapliga undervisningen. Till exempel visade resultaten att biologilärarnas värderingar påverkade deras val av ämnesinnehåll och metoder för sin undervisning. Vidare visade det sig att ämneslärarutbildarna såg sin undervisning i naturvetenskap som i huvudsak värderingsfri och att den borde förbli sådan, samtidigt som de förmedlade att värderingar bör vara en del av den naturvetenskapliga undervisningen i skolan. Forskningen som presenteras i denna avhandling ska i huvudsak ses som en utveckling av och en fördjupning inom det forskningsområde som rör värderingars roll för naturvetenskaplig utbildning. Inom denna växande domän finns flertalet områden för vidare forskning, såsom naturvetares roll inom lärarutbildning eller hur lärares värderingar påverkar dess undervisningspraktik inom naturvetenskap. Genom att införliva resultat och analyser från denna avhandling till den större forskningsdiskursen om värderingars roll för naturvetenskaplig utbildning, finns möjlighet att ta oss ett litet steg närmare förslag på förändringar för lärarutbildningar, styrdokument och klassrumspraktik. Detta för att förhoppningsvis kunna motverka den negativa trend som finns bland elever i Sverige och många andra länder i världen med avseende på intresse och motivation att studera naturvetenskap i skolan.

List of papers

The thesis is based on the following articles and manuscripts. The papers will be referred to by their roman numerals in the thesis.

Paper I: It is time for a new direction in biotechnology education research

Nordqvist, O., & Aronsson, H. (2019). *Biochemistry and Molecular Biology Education*, 47(2), 189-200. https://doi.org/10.1002/bmb.21214

Paper II: Secondary school biology students' attitudes towards modern biotechnology characterised using structural equation modeling

Nordqvist, O., & Johansson, S. (2020). *Eurasia Journal of Mathematics, Science and Technology Education*, 16(2), em1822. https://doi.org/10.29333/ejmste/115016

Paper III: What decides what is taught? Science teachers' values in upper secondary school in Sweden

Nordqvist, O., & Jidesjö, A. (2022). Submitted to *Science & Education* (under review)

Paper IV: What do university scientists value in science education? – interviews with scientists involved in biology teacher education

Nordqvist, O. (2022). Manuscript

Papers I and **II** are reprinted with kind permission from the respective publishers.

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Oh, what a journey life has been so far! I never ever thought this day would come, but here it is. Amazing to think that I went through a two-year vocational high school program to become an electrician as a 15-year-old, and soon am about defend this thesis for a PhD-degree. Life is a cool thing! Before I take off, there are many people who have made this endeavor possible that I wish to thank specifically. I like to organize things so I have separated the acknowledgement into two groups; academic VIPs and personal VIPs.

Academic (but also personal) VIPs

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Personal (but also academic) VIPs

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1. Introduction

1.1 Why values? The overall rationale

It may come as no surprise that there is now a growing research interest and literature on values in education in general, and in science education in specific. On a general note, values are key in decision-making and guide behavior, while at the same time having the inherent properties of being stable and long-lasting. To science students, science teachers and science teacher educators, these features permeate their everyday professional educational practice and therefore deserve research attention. This thesis adds dimensions to this emerging research discourse by exploring aspects of values of three important actors in science education – the science student, the science teacher, and the university scientists in science teacher education.

Values have always been an intricate part of science education, whether outspoken or not. Ratcliffe (2012) illustrate this when writing *All science classrooms are thus imbued with values, even if teachers consider that the science they teach is 'value-free'. The inculcation of science as 'value-free' knowledge is itself a value position* (p.S35). Hildebrand (2007) second that in stating *values have always been explicitly and/or implicitly taught through the science curriculum because no curriculum is ever a value-free zone* (p.45). That the values-domain in science education is open to further research is clear, as there, for example, is no consensus in the science education community regarding which values should be included in a given science curriculum (Hildebrand, 2007). More than a decade later, Corrigan et al. (2020) expanded on this by stating that …*tensions remain in [science] curriculum development and implementation, as evidenced by the continued diversity of views about what and whose values matter most* (p.4). With these examples from literature as a backdrop, it becomes evident that further studies on aspects of values in science education and how they affect teaching and learning in schools is both needed and important.

The inherent properties of values mentioned are key aspects for any actor in any educational setting, and how values affect the educational practice certainly deserves exploring. Particularly values held by the key actors in educational practice; science students, science teachers, and science teacher educators – in this thesis focusing on the upper secondary biology education context. Values will make visible

dilemmas, differences and discrepancies between how these actors view relevant science education. An expanded values discourse has great potential to develop science education in order to increase science student interest and motivation to study science. This thesis strives to inform the growing research body on the importance of values in science education.

1.2 Values in science education research

In the literature, it is reported that many students value science education in a negative manner (Christidou, 2011; Osborne et al., 2003; Potvin & Hasni, 2014a, 2014b). Students' disengagement with science in school has consequences for important educational aims, e.g., educating citizens in a science for all agenda and at the same time preparing some for future science studies (Osborne & Dillon, 2008). Many secondary school students experience school science as dull, not engaging and they do not see the relevance of science to their lives (Christidou, 2011; Jidesjö et al., 2009; Sjøberg & Schreiner, 2006), which constitutes ways of valuing science education. Such values are what many science teachers meet in the teaching of science in school, since they are the ones that present science content in schools and engage with students on a daily basis. Further, university scientists hold a key position in their role as science teacher educators, as their valuing of science and science education will affect the student teachers, and subsequently the science students in schools. Hence, important actors such as science students, science teachers, and scientists in teacher education, are useful in researching how science education can be developed and potentially find remedies to this negative trend.

That science students value school science as disinteresting, non-motivating and irrelevant is a phenomenon that has been identified for decades by research in science education. As a response to this negative trend, several research initiatives as well as curriculum development projects to turn the tide to make science education feel relevant, interesting and motivating to students in school, have seen the light. Looking into the history of science education is informative and shows that the view on values in science education can be argued to have changed over time. A brief

historic overview of some key selected research themes, with a values-lens, is therefore added to frame the thesis.

Looking back historically a few decades (mid 60's-80's), science in schools was primarily presented as traditional science based on facts, theories and laws of nature – essentially valuing science and science education as value-free enterprises. Moving into the 80's, the importance of including technology in science education became evident as technological advances in society progressed quickly. As a response to the increased need to also understand technological advances in society, a call for a study of science to meet the needs for all students was raised. The term 'Science for All' arose (Osborne & Dillon, 2008). Science education consequently shifted focus from more traditional science to a science including distinct aspects of technology, formally described as science & technology (S&T) (Kidman & Fensham, 2020).

Research rhetoric changed in the late 80's and early 90's. This was a reaction to the emerging trends in science education with lower enrollment, and lower motivation and interest in school science among students. Adding societal aspects to science education was suggested by many researchers as a response to the observed negative trend (Aikenhead, 2009). This led to a paradigm shift in science education and a new acronym was introduced; STS – Science, Technology and Society. Science curricula in the majority of western countries responded to this emerging view of science and science education, where societal aspects were introduced to science education, instilling a shift from the previous more traditional views of science and scientific knowledge (Mansour, 2009). In the STS-domain, using socio-scientific issues (SSI) in science education is/was an approach around the world to further emphasize these societal aspects into the science education classroom practice (Aikenhead, 2009; Mansour, 2009).

Just after the turn of the century, a further developed discourse with yet another acronym attracted a growing number of researchers; science identity (SI). In short, science identity describes whether an individual, such as a school student, wants to become a "science type person", as well as the socialization of individuals into the norms and discourse practices of science (Brown, 2004). Three driving forces behind creating science identity are described as (1) a sense of community and

affiliation; (2) built by consistent attitudinal factors; (3) a match between school science and real science (Vincent-Ruz & Schunn, 2018). These descriptions of the nature of science identity by Brown (2004) and Vincent-Ruz and Schunn (2018) share distinct features with the discourse on values in science education presented in this thesis. Therefore, it is not surprising that research on science identity and values in science education show significant temporal overlaps in research interest. Even though not clearly outspoken, it is obvious that several aspects of the science identity discourse recognize the importance of values.

Are the values that permeate science education drifting over time? It seems like that may be the case, as research indicate that views on how science and science education is valued have changed over the last few decades. From a predominantly value-free science education, via the frameworks of S&T and STS with their focus on societal values and a more "journalistic" perspective of science, to an emerging (or future?) value-based science education, in part framed by science identity (SI). A generalized view on this development is depicted in figure 1. Even though much of current educational research embrace the idea that values are an intricate part of science education, some researchers note that science education practice still wrongfully persists with presenting an idealized view of science as objective, detached and value-free (Osborne, 2007).

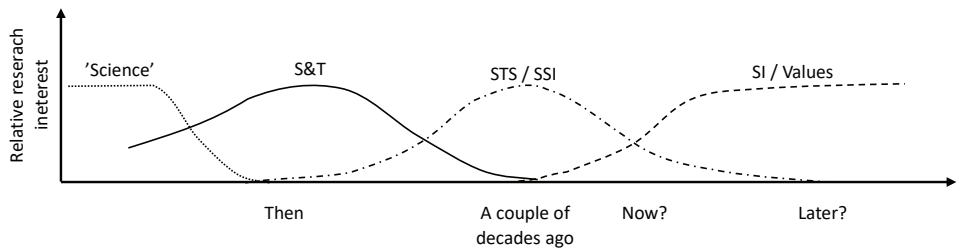

Figure 1: Generalizations of selected trends in research on science education over the last few decades and their relative research interest.

As science students still perceive school science as dull and boring, it seems like initiatives such as STS, SSI, and scientific literacy have not been as successful as was intended. Therefore, research on science education needs to continue to investigate

alternatives and/or extensions of previous research. Could a focus on the nature of science, science identity, and further research on values in science and science education be a fruitful avenue? It is quite possible and promising, and definitely worth exploring. This thesis therefore focuses on exploring the variation of values evident among actors in science education, to expand the research understanding in the domain.

1.3 The empirical setting explored

The main setting explored in this thesis is that of upper secondary school biology in Sweden. **Paper II** and **III** used survey data from upper secondary school biology students (Paper II) and biology teachers in the same setting (Paper III). **Paper IV** analyzed interview transcripts of university biology scientists teaching in the teacher program for upper secondary school biology student teachers at the University of Gothenburg, Sweden. In the scoping review presented in **Paper I**, a wider educational context was targeted, but the vast majority of articles identified from the international scene were from the upper secondary biology school setting.

In Sweden, schooling is compulsory from pre-school through grade 9 (15 years old). Beyond that, the three year upper secondary school is elective but with a 99% enrollment (OECD, 2019). Upper secondary school is divided into 18 different national programs in two different categories: preparatory (six programs) and vocational (twelve programs), each with different educational focus and with a defined set of courses to meet this focus. Although all national programs give basic qualification to attend university, preparatory programs also satisfy the requirements needed for university studies in specific subject areas. Taking specific courses in biology are mandatory in two of these programs – the Natural Science Programme (preparatory) and the Natural Resource Use Programme (vocational), where the former attracts about 15% of all upper secondary school students, and the latter about 3% (Skolverket, 2018).

How science teacher education programs are set up for educating upper secondary schools student teachers varies among Swedish universities, especially when it comes to how the discipline specific studies for student teachers are

organized. At some universities, the student teachers take courses, in for example biology, with regular undergraduate biology students, while at other universities, science student teachers take courses aimed specifically for them. Further, at some universities the discipline specific studies are organized under each department's discipline (e.g., department of biology, or similar), while at other they are organized under an educational department (e.g., department of education, or similar). The university scientists interviewed for **Paper IV** all belong to biology discipline departments at the University of Gothenburg and teach groups consisting of only student teachers preparing to become secondary school teachers.

Much of the discussion in this thesis concern science education research, while empirical data comes from the science sub-discipline of biology and in part from the sub-sub-discipline biotechnology. The context of biology then functions as a proxy for science education at large. This is a relevant assumption, as inherent properties of science values are evident and shared among all science disciplines (e.g., physics, chemistry, biology), even though the biology context is especially suitable for values discussions in science. This stance is argued further in section 2.3 in the thesis.

1.4 Connecting the dots – how the papers are interrelated

This thesis is the crescendo of a research journey that initially focused on the big picture of biotechnology education research over the last decades, then moving on to research on students' and teachers' attitudes in upper secondary school biotechnology education. As time progressed and insights were gained from this early research, the lens was adjusted slightly to focus on aspects of values in science education research. The two studied socio-psychological constructs of 'attitudes' and 'values' are related in that attitudes are seen as the expressions of values held by an individual. Values are considered to be stable and shaped early, and these inherent properties indicate that they are affecting teaching and learning in schools in fundamental ways (Corrigan et al., 2020; Corrigan et al., 2007). An overview of the constructs and papers, included in the thesis, are presented in figure 2 and the constructs are further discussed in section 2.1.

Paper I sets the stage for the thesis by describing the research context through a literature review with a historical perspective, to find potential trends in research on science education, particularly research on biotechnology education in schools. From the review it became evident that certain research aims, methods and concepts were over-represented, and that it would be necessary to dig deeper into the domain. To then move further and explore constructs under-represented, to attempt at making casualty claims from data, and to suggest development possibilities for science education. Findings from **Paper I**, indicate that the research explored was less about developing science education and more for the sake of expanding the research domain. To increase understanding, the next step in the thesis was to dig deeper into the world of science students' attitudes in biology education.

Paper II takes the research further by categorizing upper secondary biology students' attitudes towards biotechnology. This was done by using a novel analytical model in the context, to attempt to make causality claims using the attitudes construct. By implementing a novel analytical approach to the research context (i.e., structural equation modelling), possibilities to develop science education was argued for. Results show that different aspects of attitudes (cognitive, affective, and behavioral) come into play in educational practice, and that they should all be attended to when planning for science education that students deem as interesting and motivating. As the students' non-epistemic personal values theoretically underpin their attitudinal expressions explored, the attitudes analyzed also implicitly indicate the values held by the students in the specific context of modern biotechnology. Science teachers are key players when it comes to setting up science education that meet the students' needs and wants of a more relevant, interesting and motivating science education. Cue **Paper III**.

Paper III implements values as the analytical lens when studying upper secondary school biology teachers' non-epistemic values. Exploring values held by science teachers and how these values affect the teaching offered, became the next natural step. This study found that teachers' selection of content and methods was affected by their views on values inclusion in science education. Teachers that are more skeptical to include values will offer different education to their students than more positively inclined science teachers. Then the next question arose – where do

the science teachers' values come from? **Paper IV** attempts at gaining some insight on this question.

Paper IV takes the thesis to its final destination. This is done by exploring values held by university scientists involved in science teacher education. Since values affect teaching in schools, as found in **Paper III**, the study took aim at values held by science teacher educators in relation to science and science education. Interviewing university science teacher educators, albeit a small sample, indicated that the scientists interviewed do not teach the student teachers with their future teaching profession in mind. Instead, they describe their teaching as similar to that of biology undergraduate students. In relation to values, they almost unanimously see science and their teaching as value-free and that science education should be that way. Finally, they had not thought of how they value science and how science education may affect the values held by science teachers, although they acknowledged that it may be that way.

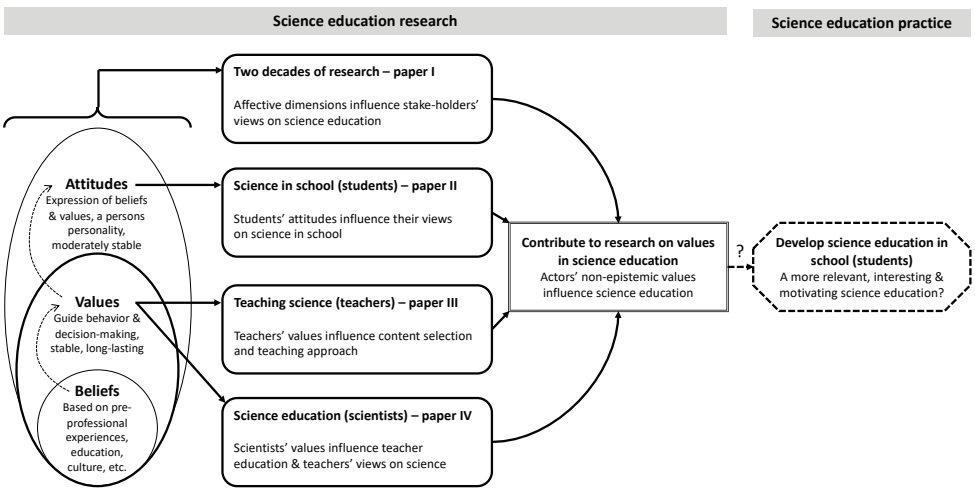

Figure 2: Overview of analytical constructs used and their relation to the four science education research papers the thesis rests upon, and also the over-all rationale for the thesis. Descriptions and relationships of constructs adapted from Fishbein & Ajzen (1975), Halstead (1996), Pajares (1992), and Schwartz (2012).

1.5 Thesis aim

This thesis sets out to investigate the role of non-epistemic values in science education from three actors' perspectives – the science student, the science teacher, and the science teacher educator in the context of biology education in upper secondary schools in Sweden. The focus is on exploring the variation and character of values among these three key actors in science education. An over-arching goal is to use the empirical findings to discuss the role of an emphasized research discourse on values as a means to develop science education practice to turn the tide on the evident decline in student interest and motivation to study science in school. The four papers will serve as a sounding board for the discussions on the importance of a values discourse in science education research. With this said, the thesis will not attempt at proving or explaining specific results, or even suggesting specific changes to science education practice, but rather use results in a fruitful discussion to inform the emerging research domain of values in science education.

2. Theoretical point of departure

This thesis is formally written as a part of a graduate program in the *Natural Sciences, Specializing in Educational Science* at Sweden's only interdisciplinary graduate school in educational science - the *Centre for Educational Sciences and Teacher Research (CUL)* at the University of Gothenburg. As the graduate program and this thesis rest on an interdisciplinary foundation, the theoretical framing will reflect both domains (i.e., the natural and educational sciences) by using a conceptual framework to analyze the quantitative and qualitative data collected. In this case, a defined socio-psychological construct of values will function as the analytical lens used in the thesis (Halstead, 1996; Koster & de Regt, 2020). This theoretical, methodological and analytical approach share features from both the traditional natural sciences and the educational sciences, and therefore highlights the interdisciplinary aspects of the graduate program. In research on values in science education, where this interdisciplinary thesis rests, the use of values as a socio-psychological construct is

by far the most common analytical approach. By using a theoretically grounded values-construct as the analytical tool, the values-aspects sought after in the thesis become visible. Pajares (1992) wrote that *All broad psychological constructs at some point must come before the reductionist, multidimensional, or hierarchical chopping block to better suit the needs and requirements of research* (p. 315). This statement pinpoints the need to define constructs used in any research analysis, which in this thesis specifically is the socio-psychological construct of values.

2.1 Values and closely related constructs

Theoretically, this thesis rests on a conceptual framework rooted in a philosophy of science that recognizes the importance of values. Values can be investigated from a multitude of perspectives, such as students, teachers, curriculum, teaching materials, culture, parents, and social media (Corrigan et al., 2020; Corrigan et al., 2007). In this thesis, perspectives of values held by secondary school biology students, secondary school biology teachers and university scientists as educators are emphasized, with an extra emphasis on the latter two. Apart from the different possible research perspectives on values in education, the multifaceted construct of values in and of itself can be perceived and defined in different ways. For example, epistemic versus non-epistemic values in relation to science and science education are important aspects to relate to (Pournari, 2008). Koster and de Regt (2020) describe these epistemic and non-epistemic values in relation to science in useful terms as *Epistemic values are those values that are conducive to an important aim of science knowledge production […] that apply to scientific theories: accuracy, consistency, scope, simplicity, and fruitfulness.* (p.126) and they continue to state that *Non-epistemic values, on the other hand, would include, for example, cultural, moral, economic, and political values and also more personal values based on religious commitments, interests, or loyalty to colleagues and sponsors* (p.126). Even though these descriptions are in relation to science and scientists, especially the non-epistemic values used in the thesis are transferrable to the context of science education. Unless stated specifically, values referred to in this thesis are non-epistemic values. In current research and discussions on values in science education, the broad and pragmatic definition of values by Halstead (1996) is often adopted (Corrigan et al., 2020;

Corrigan et al., 2007), where Halstead states that values can be defined as: *principles, fundamental convictions, ideals, standards or life stances which act as general guides to behaviour or as reference points in decision-making or the evaluation of beliefs or action and which are closely connected to personal integrity and personal identity* (p.5). Such a broad definition allows for consideration of a wide range of factors that influence science education. In **Paper III** and **IV** this definition was used for analysis, in part to be aligned with previous research on values, but also as it provided the analysis with a useful tool. Especially in combination with the description of the non-epistemic nature of values described above. The construct of beliefs is closely related to values and the distinction between the two is a fine one (Schwartz, 2012). At times they are even used interchangeably (Simon & Connolly, 2020). A graphical illustration of how the constructs can be related and described is presented in figure 3. Pajares (1992) describes beliefs as assumptions people believe to be true about the world based on their knowledge and experience. Values, as described by Schwartz (2012) and defined by Halstead (1996) above, then stem from these beliefs and are ultimately what people deem important. Attitudes is a closely related complex psychological construct, just like values and beliefs. A frequently referred to working definition that describe the nature of attitudes state that attitudes are …*a learned predisposition to respond in a consistently favourable or unfavourable manner toward an attitude object* (Fishbein & Ajzen, 1975). **Paper II** digs deep into the construct of attitudes and even take the concept a bit further than the thesis aims to do. One key feature of attitudes, which differentiate attitudes from values and beliefs, is the response to stimuli, e.g., what a person says or how the person acts. This attitudinal response is then a mirror of the values the person holds. Values have inherent properties of being stable and long-lasting, what a person holds as important, as well as acting as a general guide to behavior and a reference-point in decision-making (Halstead, 1996). How the three constructs are interrelated is depicted in figure 3.

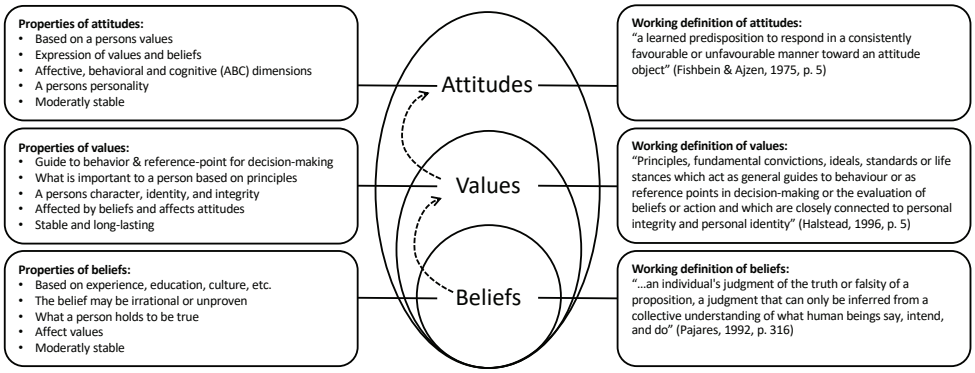

Figure 3: Overview of the socio-psychological constructs beliefs, values, and attitudes as well as their relations and characteristics, together with working definitions of each construct (Fishbein & Ajzen, 1975; Halstead, 1996; Pajares, 1992; Schwartz, 2012)

Values serve as an important area of research in science education as students, teachers, and teacher educators' respective values affect several aspects of science education. All actors in educational practice (and elsewhere) make decisions and behave in a certain way based on their values. These inherent properties of values trigger research interest, as a deepened understanding has the promise to actually change and develop science education for the future.

2.2 Affective constructs explored in science education research

In research on education in general, and consequently in science education, non-cognitive aspects, or affective dimensions, have attracted researchers' attention as they play important roles in learning science (Alsop & Watts, 2003; Rahayu, 2015). Examples of these affective constructs are the psychological constructs of belief, attitude, interest, motivation, self-concept, and values. However, the feat to distinguish between these has proven difficult and there is not much agreement on how to describe them (Schlöglmann, 2009). It comes as no surprise that affect, as an overarching construct, is by psychologists arguably the most complex to describe (Allen & Friedman, 2010) as the affect construct attempts at including several individually complex constructs. As can be noted, both values and attitudes are

included under the affective umbrella, as described here. Since they are interrelated, it is of great importance to be able to differentiate between them in analytical discussions.

Even though it may be difficult to keep the constructs apart, various affective constructs have been explored thoroughly in the context of science education research, in a vast number of studies, due to their perceived important role in learning science. **Paper I** reviews articles written on these and other constructs in biology education research over the last two decades. It was found that research in the domain between 1999-2019 presented primarily quantitative, non-experimental design methods with descriptive data (frequencies, central tendencies, correlations, etc.). Also, most publications were from the years of 2007-2012. The vast majority investigated students' attitudes towards and knowledge in/about biotechnology. Conclusion was that research needs to move ahead and not just map attitudes and knowledge with non-experimental methods. It was also concluded that attitudes, the most researched affective construct, seems to have lost most of researchers' interest evident earlier.

2.3 The disciplinary context

Science constitutes an extensive body of knowledge with various values connected with its development; both epistemic and non-epistemic values. One convenient and especially relevant educational domain to study aspects of values is biology, in general, and biotechnology education in specific. This is due to the many technological advances, in for example biotechnology, that have been associated with public controversy and are inherently value laden (Bauer, 2005; EC, 2013; Sax & Doran, 2019). Buntting & Jones (2020) argue that biotechnology education is a suitable domain for studying the values discourse in science education, for similar reasons. Further, biology teachers have been shown to be more likely to include value laden controversial issues in their teaching, compared to colleagues teaching other subjects (Sadler et al., 2006). By the implementation of biotechnology education in a large number of national curriculum frameworks in the last two decades, the importance of biotechnology education has been recognized internationally (Steele

& Aubusson, 2004). Based on these arguments, biotechnology education is a particularly suitable context for research on aspects of values in science education and is therefore the main educational context of the thesis.

The empirical magnifying glass in this thesis is on upper secondary school biology education in Sweden, while the discussion in the thesis is on science education in more general terms. The specific context of biology education is particularly interesting to study in relation to the values held by the different actors. By using this science values context, it is likely that several aspects of values may surface and be of research interest. Indeed, variation of aspects of values among and between biology students, biology teachers, and university biology scientists was identified. This thesis shows that there is variation within biology education, but whether the disciplinary context play a role cannot be fully understood until other science disciplines have been investigated. Currently, there is a void in research here, as no studies have been identified from other science disciplines. Whether the findings and discussions can be extrapolated to an international scene is another question without a clear answer. Any claims on international generalizations would be speculative at this point.

3. Material and methods

3.1 Overview of empirical data and methods

Commonly, methods used in research are described as being either quantitative or qualitative. A quantitative method is seen as the process of collecting and analyzing numerical data to find patterns, make predictions, test casual relationships and generalize results. Qualitative method on the other hand is the process of inquiry that seeks an in-depth understanding of social phenomena within their natural setting. The latter focuses on the "why" rather than the "what" of social phenomena and relies on the direct experiences of human beings. This is a way of referring to research and research methods that may cause more confusion that intended though. A method or a methodology cannot *per se* be qualitative or quantitative, only research

data can be qualitative or quantitative (Åsberg et al., 2011). The research method and analysis tool chosen and the results from the analysis made from this data will suggest if claims of causality, generalizability, or "why"-inferences can be made. Also, a "qualitative method" could generate quantitative data, and vice versa. Based on the reasoning above, this thesis will not refer to the methods as being either quantitative or qualitative, but rather that the data analyzed has these features.

In the four papers serving as the foundation for the thesis, different methods to collect and analyze data were implemented. **Paper I**, **II** and **III** collected quantitative data with the intent to find patterns and categorize, and attempt at generalizing the results to a larger population. For **paper IV** no such claims were made, as the data collected was of qualitative nature with the intent of gaining insights and individual nuances on the informants' perspectives. Table 1 presents an overview of methods used and data collected. Conceptually, **Paper I** was more general and focused on the character and trends of various concepts or constructs discussed in biotechnology education research. **Paper II** deepened the discourse by focusing on upper secondary school biology students' attitudes and aspects thereof within biotechnology education. **Paper III** and **IV** dug deeper into the values construct in science education by using upper secondary school biology teachers and university scientists as informants.

Table 1: Overview of aims, empirical data, and analytical methods used in **Papers I-IV**

Papers	Aim of study	Empirical data	Analytical method
Paper I - It Is Time for a New Direction in Biotechnology Education Research	Identify and characterize the research domain and further to find potential temporal trends	Published peer-reviewed research articles (n=64) between 1999-2016 in biotechnology education research	Systematic scoping literature review (Arksey & O'Malley, 2005)
Paper II - Secondary School Biology Students' Attitudes towards Modern Biotechnology Characterised using Structural Equation Modeling	Characterize student attitudes towards biotechnology by applying an analytical method not previously used in the context to potentially make causal inferences. Increase the understanding of how attitudinal dimensions affect biology education	Upper secondary school biology student responses (n=1503) from an author constructed national survey	Confirmatory factor analysis (CFA) and structural equation modelling (SEM) (Brown, 2015; Kline, 2016)
Paper III - What decides what is taught? Science teachers' values in upper secondary school in Sweden	Characterize teachers' non-epistemic values and to elucidate potential associations between these values and a set of hypothesized explanatory factors	Upper secondary school biology teacher responses (n=131) from an author constructed national survey	Latent profile analysis (LPA) and non-parametric testing (de Vaus, 2001; Muthén, 2008)
Paper IV - What do university scientists' value in science education? – interviews with scientists involved in biology teacher education	Portray views and values of science and science education held by university scientists involved in science teacher education	Transcripts (n=5) from semi-structured interviews with university scientists teaching discipline specific biology to student teachers	Thematic analysis (Braun & Clarke, 2006)

Ethical considerations relating to research in educational science, stipulated by the Swedish Research Council (Vetenskapsrådet, 2017), were adhered to in all aspects of this thesis and the individual papers.

3.2 Strengths & weaknesses

As the thesis attempt to show the importance of values in science education from different perspectives, the fact that three identified main actors in science education were used as informants can be seen as a strength of the thesis. On the other hand, the thesis project as a whole was initiated with the intent to study attitudes, which

during the course of research developed into research on values. It would have been more stringent if the same construct was used throughout. This shift in analysis construct could be seen as a strength though, as it indicates that attitudes were not purposeful for the research sought after. Further, by using an established definition in the research discourse of values in science education, the results and discussions resonates well will current research in the domain. The use of different methods to collect data could be seen as both a strength and weakness as different methods have advantages and disadvantages. The use of representative survey data for **Paper II** and **III** allows for some generalizations, while, for example, losing the possibilities of exploring nuances in the questions that interviews allow for. Even though the interviews in **Paper IV** gave at hand interesting and individual responses to analyze, the sample size and the purposeful selection of interviewees do not allow for generalizations.

3.3 Validity & reliability

Reliability is, in short terms, the overall consistency of a measure, while validity in general terms is the correlation between the theoretical definition and the operational definition. That is, if testing or a method really measures what it is supposed to measure (de Vaus, 2001). With regards to reliability, the papers used different approaches, such as statistical reliability tests, (e.g., Cronbach's α and "split-half"), large representative samples (Paper II & III), and the use of interview-guides and audio recordings (Paper IV) to meet reliability demands (Shadish et al., 2002). Various forms of validity claims, i.e., construct validity, statistical validity, external validity, etc. (Shadish et al., 2002) were aimed for by using applicable methodological approaches in the respective papers. With regards to the overall claims of validity and reliability in the discussions and arguments in the thesis, there is a strive to stay within the boundaries of what can be inferred from the papers informing the thesis. Any definitions, descriptions, generalizations, inferences, and claims of causality, especially with regards to reliability and validity, are therefore cautiously presented.

4. Values among actors in science education

4.1 Key actors studied

An overarching goal with this thesis it to present and discuss puzzle pieces to the values in science education research discourse. These pieces may in turn aid the research community in developing science education practice to achieve a science education that students deem as interesting, motivating, and relevant. It would be a great undertaking by many actors to turn the tide in science education to make it more interesting, motivating and relevant to students. The three actors discussed in this thesis (e.g., biology students, biology teachers & university scientists in biology teacher education) play important roles, but obviously other actors in the educational context are crucial too. For example, policy makers, curriculum developers, and researchers from within science education as well as in other research disciplines. It would be a huge feat to accomplish a tide-turning. This thesis argues that the variation of values held by especially three actors in science education are key in this endeavor. The science students' perspectives are important, and so are the perspectives held by science teachers. A third key actor worth exploring further are university scientists participating in teacher education. An increased understanding of the variation and character of values from these three actors, evident from the research papers behind this thesis, can inform the research community on values in science education. A presentation of the three actors and their values will be discussed in the following sections.

4.2 Biology students in upper secondary schools

Overall, students do not value science education in a positive manner. On the contrary, research show that they deem science education in schools as dull, boring and irrelevant (Christidou, 2011; Osborne et al., 2003; Potvin & Hasni, 2014b; Sjøberg & Schreiner, 2006). The words of Oscarsson et al. (2009, p.19) portray the essence in this when they conclude that *School science seems to offer mostly a backward-looking view of well-established scientific knowledge while students' interests are concerned with what is of immediate importance and the future.* By studying aspects of science students' values,

valuable insights can be gained and serve as a research foundation for the development of science education – both in the classroom practice context, and in a larger curriculum context.

In **Paper II**, the socio-psychological construct of attitudes is explored in relation to upper secondary school students and biology education. The relationship between attitudes and values, based on the theoretical framing in this thesis, is that attitudes portray the expression of values held by an individual. Consequently, the values held by the survey students would have to be inferred implicitly from their expression of attitudes in the survey responses. Unpublished findings from the student survey that **Paper II** rests on, show that the upper secondary school biology students strongly support the inclusion of values in science education in general. Further, this support for values inclusion in biology education among the surveyed biology students compared to surveyed biology teachers show a largely similar pattern. When surveyed on what topics in biotechnology that interested the students most, topics with inherent properties of values, ethics, etc. came out on top. Even though these results are unpublished, they align well with research stating that the students valued the inclusion of values-based topics in science education (Ekborg, 2008; Lindahl et al., 2011; Osborne et al., 2003). Hence, even though science students in general do not value science education in a positive way, there are areas that students deem as interesting, motivating and relevant. One conclusion in the analysis on students' attitudes made in **Paper II**, highlights the importance of including affective and behavioral dimensions in teaching biotechnology in schools, and not merely focusing on cognitive dimensions. In other words, when values are discussed in the science classroom, students show more interest and motivation to study science. In short, science students value inclusion of values in science education in a positive way.

4.3 Science teachers in upper secondary schools

The results and analysis from **Paper III** conclude that science teachers' non-epistemic values affect the education their students are offered, both in relation to what content is taught and also the teaching method itself. The majority of biology

teachers surveyed support values inclusion, while a smaller group, with an overrepresentation of more experienced teachers, were more skeptically inclined. These two groups of teachers will offer their students different science educations, where the more skeptical teachers are less inclined to include topics with aspects of values in their teaching, as well as less interested in including methods supporting values-discussions. It is evident from several studies that there is a clash in what science teachers teach and what science students are interested in learning (Kidman, 2009; Oscarsson et al., 2009; Potvin & Hasni, 2014b), but the importance of science teachers' values in this clash has not previously been explored in this way. So, to cater to what interests and motivates students to study science (i.e., values, ethics, etc.), understanding values held by science teachers is an important avenue to explore further in research.

As values guide behavior and decision-making, according to the theoretical conceptual framework of this thesis, the results may not be surprising *per se;* teachers more skeptical to values inclusion choose to include less values-infused topics in their teaching. But if other core aspects of values are adhered to, such as that values are stable, long-lasting, and tend to be shaped prior to professional experience, a different picture is painted. Primarily, where the science teachers values stem from, and how and if values develop as teachers become more and more experienced. One possibility is that science teachers' values, in relation to the domains of science and science education, stem from their pre-service science teacher education. This hypothesis will be explored and discussed in the next section. It is clear though that science teachers' non-epistemic values affect the teaching practice and the values included in science education.

4.4 University scientists in science teacher education

How university scientists value science and science education is likely to implicitly affect values held by science teachers in schools and in extension even the science education offered to students in schools. Science teachers may then function as unintentional mediators of values between the university and school settings. This may or may not be desired, depending on what constitutes the values. For example,

are the views and values of science and science education as portrayed in science teachers' education the ones expected to be expressed in science education in schools? Although **Paper IV** interviewed only a small number of university scientists teaching biology to student teachers, they convey that their disciplinary teaching does not recognize the full scope of student teachers' future professional careers. They primarily see themselves as presenting value-free facts in a perceived mostly value-free setting.

Over all, the university scientists teaching biology to student teachers are quite homogenous in their interview responses. Since only five scientists from one teacher education program at one university were interviewed, it is not possible to make generalizations to a larger population, and conclusions must be seen in this narrow context. However, the results may be used as a reference point for discussions and therefore a presentation of the results will be attempted. The scientists interviewed see the nature of science as a primarily value-free enterprise. They further state that the biology education they offer to the biology student teachers does not differ in comparison to that of regular undergraduate biology students. If anything, the student teachers get a "biology light" education as one respondent described the student teacher education. They do not teach in relation to the future professional needs of the student teachers, and they hold a value-free approach to their teaching. The scientists also state that they think that science education in schools should have a more societal view compared to the science education offered to the student teachers at the university. They thereby acknowledge that the teaching they offer and the science values they instill during teacher training is not aligned with the teaching that they think should be offered to students in schools. When asked if they had considered that how they view and value science and science education impacts students in schools they all, with one exception, stated that they had never thought of that before. In short, university scientists teaching science to science student teachers do not seem to value values in their practice. The findings presented here suggest that there is a need for continued research in the area.

5. Concluding remarks

Valuing values in science education research could be a tide-turner for the evident negative trend in interest and motivation to study science among science students. This thesis contributes to the domain of research on values in science education by showing that there is a variation of values within and between key actors in science education. The main take-home message is that non-epistemic values held by science students, science teachers, and science teacher educators directly and/or indirectly have the potential to affect the science teaching offered to students in upper secondary schools in Sweden. This in turn affect what science students have the opportunity to learn, and also if the students perceive their science education as interesting, relevant and motivating – key factors identified by research for successful learning in science. As science educational research initiatives such as STS, SSI, and scientific literacy have not been able to change science students' negative valuation of school science, there is a need to adjust research focus. The emerging research on values in science education, i.e., the research context of this thesis, is one promising area of research worth expanding further.

The analytical lens of values used in this thesis allows for shedding light on what guides behavior and decision-making in the educational practice. Making decisions are crucial for all actors in science education, so that, for example, teachers' non-epistemic values affect their practice is not far-fetched in theory. Similar results were also evident in the studies on science teachers and university scientists teaching science to student teachers. The findings presented in this thesis will hopefully expand the understanding of the importance of values to the growing research community on values in science education, as well as to other stakeholders in science education – in Sweden and internationally. The discourse on values in science education is a discourse of great promise.

5.1 Implications for science education in schools

Figuratively, this thesis contributes to the values in science education domain by adding a few more puzzle pieces to a puzzle of unknown size and shape. More research is needed before the research community can and should advice practitioners in science education – at least for large scale implementations. Even though there is a promising and growing body of research on values in science education, much is yet to be explored. However, this thesis imply that values do play an important role in science education.

On a small scale though, implications for science education can be hypothesized from findings in this thesis. For example, it is important to be aware of that science teachers' non-epistemic values affect the selection of content and methods, and discuss that among teachers in schools and in teacher education programs. Especially since these values are considered to be long-lasting and stable, and therefore need to be paid attention to in any science teaching practice. A discussion on values in science teacher education programs would also be beneficial as results show that there is a discrepancy between values held and presented by the science teacher educators at universities and the values infused in the science context the student teachers will work in. Both in regards to what constitutes the nature of science and the nature of science education. It is of essence that university scientists involved in science teachers' education also is informed about their role of instilling science values in their student teachers. As with all developing educational practices, it will take a long time for change to be evident, and research show that in order to be successful, teachers need be active participants in the change process (Mansfield & Reiss, 2020). For science students to value science education in schools as interesting, motivating and relatable in the future, something must change. Key players are the science teachers and the science teachers' educators, and by increasing the understanding of the landscape of values, as this thesis attempts, there is a possibility for a positive development of science education in schools. More research with different approaches, in different contexts, and over time to lay a foundation is crucial though, before development programs are presented and implemented.

5.2 What is ahead?

As with all exploratory research, there are many holes to fill in this emerging research domain. With the insights gained through this thesis project, a few specific avenues would be of particular interest to study further; both temporally and spatially. For example, if someone were to follow in the tracks of the research presented here, the use of other methods to increase the level of explanatory power and claims of generalizability would increase the necessary explanatory power. It would also be valuable and important to find out if the patterns found in biology education also are evident in other science disciplines. The context in this thesis was upper secondary schools, so exploring other educational settings to develop the understanding of how aspects of values affect other educational contexts would be important. To investigate other international settings is yet another important domain to explore further, to find if and how the results from this thesis compares and contrasts to other settings, would be a very valuable addition to the research community on values in science education. As the research presented in the thesis primarily informs the research community on values in science education, it would be interesting to further research the role of non-epistemic values in the actual science classroom practice. The examples presented here are just like the tip of an iceberg, but allows for starting points for other research projects.

If the emerging research on the importance of values in science education truly takes off with evident changes in science curricula and educational practices in the future, it will be of utter interest to see if a values discourse really could turn the tide to increase interest, motivation and feeling of relevance among students in science education.

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