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ARTICLE

Upper Secondary School Science Teachers' Values in Sweden:

What Decides What is Taught?

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Abstract

There is a substantial literature in science education research showing that many students experience a lack of relevance in science education. For this reason, science teachers' selection of content and the way content is treated when exposed to students for learning purposes is an important part of the problem. In this connection, research show that science teachers' values strongly influence several aspects of teaching and learning science. Therefore, science teachers' values are important to investigate, to be empirically informed and to be able to develop science education. Accordingly, there is an increased volume of research studies about teachers' values in science education and their effects. The study presented here is part of a larger national exploration of biotechnology education in upper secondary schools in Sweden and contributes by showing variation in teachers' values and relations with practice. Theoretically, the study is rooted in a philosophy of science recognizing the potential importance of teachers' non-epistemic values. Empirically, it is based on surveyed upper secondary school biology teachers' views of the importance of including value-laden topics in their science teaching. Their responses were analyzed by latent profile analysis and non-parametric testing, to assess the variation in their views and explore associations with several explanatory factors. The results show that the surveyed teachers could be divided into two distinct groups: one favoring inclusion of value-laden topics in their teaching and another (smaller group) opposed to it. The result also shows a variation in teachers' selection of topics to teach and their teaching approach, as the former group were more inclined than the latter to include value-laden aspects in their teaching which contributes to the research literature. Furthermore, experienced science teachers were overrepresented in the group holding more negative views, a result not reported elsewhere in the research literature. The importance of the results is discussed in relation with the theoretical framing of non-epistemic values and points out the importance to further investigate underlying causes to science teachers' expressed values and ways that they might vary temporally together with ways that they cluster, as they are shown to be grouped. The result is also discussed in relation with practice in being able to make use of the evidence to develop science education.

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1 Introduction

Many students reportedly find school science dull rather than engaging, and do not see its relevance to their lives (Christidou, 2011; Jidesjö et al., 2009; Potvin & Hasni, 2014a; Sjøberg & Schreiner, 2006). Hence, they have little interest in science education (Christidou, 2011; Osborne et al., 2003; Potvin & Hasni, 2014a, 2014b). This has profound implications for important educational aims, e.g., educating citizens in a science for all agenda and preparing some for future studies (Osborne & Dillon, 2008). Key agents for addressing the problem are clearly science teachers, as they present science content in schools and engage with students on a daily basis. Moreover, several studies have shown that selecting topics and contexts that are inherently value-laden (i.e., involving subjective implicit and/or unexamined moral evaluations) in science education can improve students' interest (Krapp & Prenzel, 2011; Ottander & Ekborg, 2012; Sjøberg & Schreiner, 2006; Tytler, 2012). Others have concluded that value-laden topics are not included sufficiently in science education and should be allowed more space (Jensen & Schnack, 2006; Koster & de Regt, 2020; Reiss, 2006; Sadler et al., 2006). Kidman (2009), for example, found that many Australian teachers chose not to teach value-laden topics in biotechnology education, despite students' interest in them. Similarly, Aivelo and Uitto (2019) found that Finnish biotechnology teachers only chose to teach such topics if time allowed. In summary, poor alignment between teachers' and students' views on inclusion of values in science education may be a major contributor to students' lack of engagement.

An important factor is that all participants in the educational process, both teachers and students, bring to the classroom diverse ideas and practices based on their personal values related to science and science education. Teachers' values and beliefs inevitably influence their planning, teaching, and thus what is presented to the students (Hildebrand, 2007; Levinson, 2001; Pajares, 1992; Sutrop, 2015). Thus, "what teachers value has strong implications for what they teach, when, how and perhaps most importantly, why" (Cooper & Loughran, 2020, p. 51). At the same time, as argued earlier, what students value and deem important in science education affect their interest and motivation to study science in school. Teachers' personal values affect the science teaching offered, and by including value-laden topics in their teaching practice, a positive effect of student interest and motivation could be anticipated.

The importance of including value-laden topics in science education has been recognized for several decades (Allchin, 1999; Poole, 1995), and during the last decade, their roles have received increasing attention (Corrigan et al., 2020). This may be a response to rapid advances in science that are generating technologies that increasingly permeate all aspects of our lives, raising complex moral and ethical issues (Chowdhury, 2016). Koster and De Regt (2020) as well as Sutrop (2015) show that neither science nor science education are or can be value free enterprises. In stark contrast, Chowdhury (2016) and Corrigan et al. (2020) show that science education is often perceived by students as being stuck in a rut of boring traditional content and standard methods and therefor recognized a need to include value-laden topics in science education.

Kumarassamy and Koh (2019) and Ratcliffe (2012) show that some teachers believe that science teaching should be value-free, and issues with major social or ethical implications avoided, while others advocate their inclusion. According to Hildebrand (2007, p. 45), "values have always been explicitly and/or implicitly taught through the science curriculum because no curriculum is ever a value-free zone." In practice, Corrigan et al. (2020) conclude that many UK and Australian teachers and educators support the inclusion of value-laden topics and the associated moral and ethical issues in science education, while they also raise concerns about the inclusion. Hence, the evidence indicates a variation in teachers' values and there are corresponding studies of teachers in India, Singapore, and the USA (Kumarassamy & Koh, 2019; Sadler et al., 2006). However, to our knowledge, no previous studies have explored teachers in Sweden, or other Nordic countries, apart from the survey of Finnish teachers' practices mentioned above (Aivelo & Uitto, 2019). The study reported here (part of a larger national exploration of aspects of biotechnology education from students' and teachers' perspectives in upper secondary schools in Sweden) addresses this gap. As non-epistemic values (defined below) targeted in this study have strong socio-cultural dimensions, it is important to the research community to increase the sparse knowledge of values that science teachers actively or passively include in their teaching in diverse (including Scandinavian) settings. Moreover, the growing literature on values in science education provides little information about the variation in teachers' values, their associations with explanatory factors, and their pedagogical effects. Thus, exploration of these associations and effects was a major aim of the study.

Science constitutes an extensive body of knowledge with various values, epistemic and non-epistemic, connected with its development. A convenient and especially relevant domain to study aspects of values is biotechnology education as many technological advances in biotechnology have been associated with public controversy and are strongly value-laden, such as cloning, DNA profiling, transgenesis, and genetic engineering (Buntting & Jones, 2020). Moreover, its importance has been internationally recognized, as demonstrated by its inclusion in numerous national curriculum frameworks in the last two decades (Steele & Aubusson, 2004). Thus, this study focuses particularly on views and values of Swedish biotechnology teachers.

For obvious reasons, given the aims, the study is rooted theoretically in a philosophy of science that recognizes the importance of values. Values are multifaceted constructs that can be investigated from diverse perspectives, such as students, teachers, curriculum, teaching materials, culture, parents, and social media (Corrigan et al., 2007, 2020). In recent research and discussions on values in science education, the following broad and pragmatic definition of values by Halstead (1996, p. 5) is often adopted (Corrigan et al., 2007, 2020), "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." Important classes when addressing values and their roles in science and science education are epistemic and non-epistemic (Pournari, 2008). "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" while "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" (Koster & de Regt, 2020, p.126). Unless stated otherwise, the term values hereafter refer to non-epistemic teachers' values. A closely related construct is belief (Schwartz, 2012), and the fine (but important) distinctions between them are summarized in Fig. 1. 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), stem largely from these beliefs and are ultimately what people deem to be important. They have long-term stability, personal importance for their holders, and serve as both general behavioral guides and reference-points in decision-making (Halstead, 1996). Since values are stable, long-lasting, guide behavior, and play major roles in decision-making, teachers' values affect their teaching and what students have opportunities to learn. Thus, they clearly warrant intense attention.

The objective of the study presented here was to investigate the character of Swedish science teachers' non-epistemic values in science education. More precise, their personal valuation of the importance of including value-laden topics in biotechnology education. The study

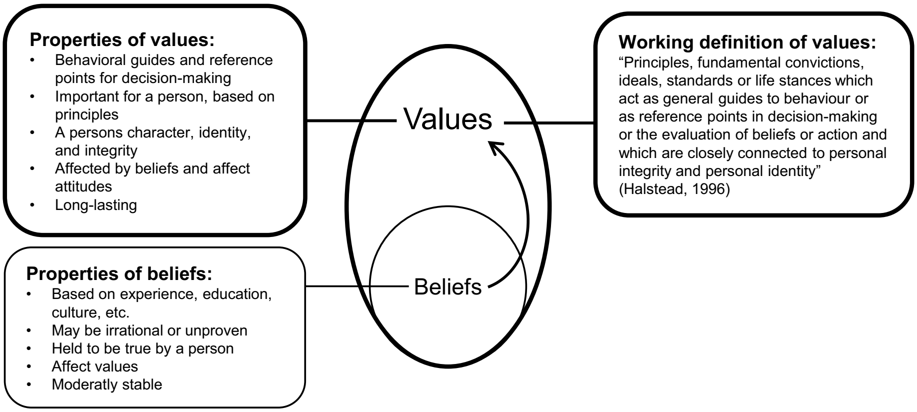

Fig. 1 Overview of the constructs beliefs and values, their relations, and characteristics, together with a working definition of values (Halstead, 1996; Pajares, 1992; Schwartz, 2012)

also explores associations between teachers' views and their statements about selection of topics to include in biotechnological education, and their teaching approaches which are discussed as potential explanatory factors. With this, we do not claim that there are other epistemic values which also contribute to how teachers act. The research design chosen in this project is concerned with the non-epistemic domain. With this framing, the study investigates variation in teachers' values and relations with practice from a science teachers' point of view, which contribute with empirical evidence about what influences how science is exposed to students. Such evidence can also assist in developing science education.

2 Materials and Methods

2.1 Study Design

In efforts to meet the objectives, the study was designed as illustrated in Fig. 2 and described in detail in the following text. In a first step, we surveyed Swedish biology teachers' views of including values (generally and specifically), the biotechnology topics they chose to teach, and their teaching approaches. We then identified groups of teachers with significant differences in these respects and explored associations with potential explanatory factors. The study is designed to characterize and explore how teachers' personal values affect aspects of their teaching practice. Therefore, in preparing the survey, the focus was placed on questions and statements which explore biology teachers' non-epistemic values.

2.2 Material

The instrument used to gather empirical evidence was part of a questionnaire we constructed on aspects of biotechnology education, based on several existing questionnaires including the Biotechnology Education Learning Biotechnology Education Teaching Surveys (BELBETS)

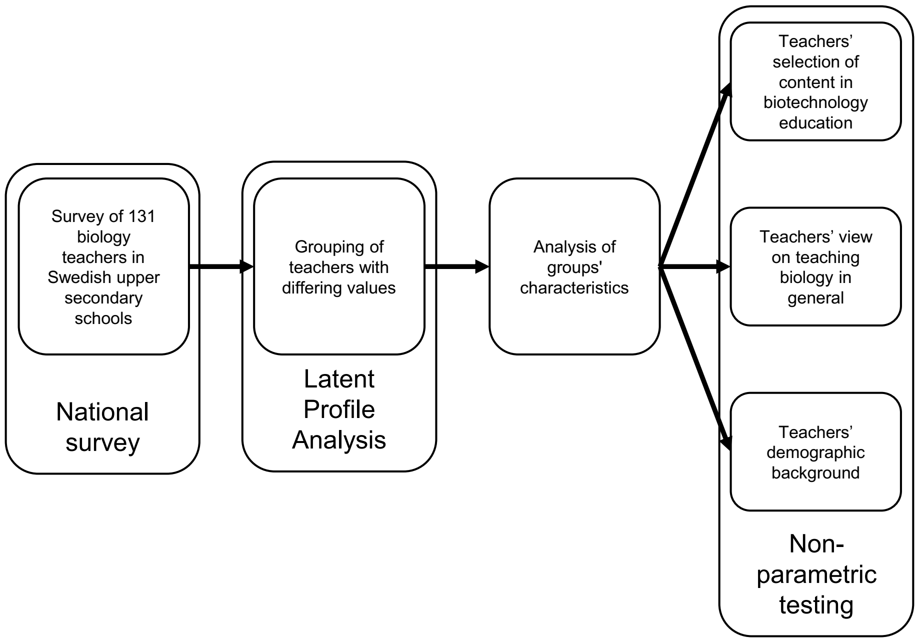

Fig. 2 Graphical description of the study design

(Kidman, 2009, 2010), Biotechnology Teaching Survey/Biotechnology Learning Survey (BTS/BLS) (Haidar et al., 2014), and Constructivist Learning Environment Survey (CLES) (Johnson & McClure, 2004; Taylor & Fraser, 1991). Adaptive translations with a pragmatic approach were made by fellow researchers in the research field, native in English and Swedish respectively, to verify that the correct language intentions were conveyed in the questionnaire (Repke & Dorer, 2021). A pilot version was tested on active teachers for revision purposes to investigate the validity and reliability of the included items. From this pilot version, the final teacher questionnaire was created. Use of these instruments provided foundations for questions and statements that had been validated in other international contexts and enabled for the possibility of some general international comparisons and discussion of the results.

2.3 Data Collection

A list of all Swedish schools offering either or both of two relevant upper secondary educational programs (Natural Science and Natural Resource Use) was obtained from the Swedish National Agency for Education in October 2017. All schools on this list ($n=439$) were contacted by e-mailing the principal (or other person with similar responsibility) and invited to participate in an online survey of teachers' perceptions of values, selection of lesson topics, and general teaching approach to biotechnology education. A link to the online teacher survey questionnaire was subsequently sent, in October 2017, to the biology teachers at each school headed by a principal who agreed to participate, together with instructions for completing the questionnaire. Each principal then decided on their school's participation. The teacher online survey questionnaire was forwarded to the biology teachers at each participating school by the principal. Questionnaire instructions for the teachers were provided by the researcher. Reminders were sent out in late November and early December 2017 to improve response rates. Due to confidentiality, it was not possible to specifically contact non-respondents, or even tell which schools participated. All questionnaires included in the analysis were returned in October to mid-December 2017, with a 13.0% response rate for teachers at all schools on the list. The representativeness of the teacher sample was assessed by comparing their demographic parameters, also acquired through the survey, with national census data (Table 1). The response rate and representativeness were deemed sufficient to consider the sample nationally representative. However, this does not exclude the possibility that they may not have been representative in terms of views. For example, teachers with views that they perceived to be stigmatized may have been reluctant to participate. Ethical

Table 1 Demographic parameters of in-service biology teachers who participated and comparative national census data for teachers of the Natural Science and Natural Resource Use Programs in the 2017–2018 academic school year

	Survey data		*National census data*	
	n	%	*n*	%
Certified to teach biology				
Certified	119	90.8	837	82.5
Not certified	12	9.2	177	17.5
Other/unsure	0	0	n/a	n/a
Total	131		1014	
Gender				
Female	77	58.8	614	60.3
Male	50	38.2	405	39.7
Other/unsure	4	3.1	n/a	n/a
Total	131		1019	
Private/municipal school				
Municipal	87	66.4	26795[a]	76.2
Private	31	23.7	8348[a]	23.8
Other/unsure	13	9.9	n/a	n/a
Total	131		35143[a]	
Primary teaching program				
Natural science	104	79.4	348[b]	79.3
Natural resource use	27	20.6	91[b]	20.7
Other/unsure	0	0	n/a	n/a
Total	131		439[b]	
Teaching experience				
< 5 yrs	33	25.2	n/a	n/a
5–10 yrs	24	18.3	n/a	n/a
10–15 yrs	19	14.5	n/a	n/a
15–20 yrs	19	14.5	n/a	n/a
15–20 yrs	19	14.5	n/a	n/a
> 25 yrs	17	13	n/a	n/a
Total	131			

[a]Teachers of all programs nationwide

[b]Number of schools offering specified programs nationwide

guidelines pertaining to research in educational science issued by the Swedish Research Council (Vetenskapsrådet, 2017) were followed in all stages of the study. Due to the nature of the study, no ethics approval was necessary, and data was handled according to guidelines dictated by the council.

2.4 Sample

Teachers of biology elements of the national Natural Science and Natural Resource Use Programs were targeted as biotechnology is part of these programs' biology curricula. Table 1 provides demographic information about the participating teachers and comparative official national census data for teachers of the two educational programs, provided by the Swedish National Agency for Education for the 2017–2018 academic school year. The census data were collected by the Agency in October 2017, in alignment with the questionnaire's distribution.

As shown in Table 1, the sample of participating teachers did not differ substantially demographically from the national populations, according to the census data. However, higher proportions were certified to teach biology than the national averages, possibly because the principals may have tended to pass the questionnaires to teachers who had permanent or long-term positions. Furthermore, a lower proportion were teachers in municipal schools compared to the national averages and a significant group checked the category "other/unsure" in the questionnaire. This latter group could possibly include teachers in Swedish schools abroad run by the state rather than a specific municipality, but it is also possible that some teachers were unsure as all schools in Sweden (municipal and private) have the same funding system and are mandated to follow the national curriculum.

2.5 Survey Items

The survey components used to acquire empirical data to explore the teachers' values, topics they teach, and teaching approaches were Likert-type items with five ordinal response categories ranging from "Strongly disagree" to "Strongly agree," scored -2 to $+2$. These included three statements regarding their views of including values in biology education, 10 on their selection of biotechnology topics and 10 on their approaches when teaching biology. Table 2 presents the items regarding teachers' views of including values, which were used in latent profile analysis (LPA) to characterize their views of including values and identify groups of teachers whose responses significantly differed. The items were developed by Kidman (2009) as a part of the Biotechnology Education

Table 2 Survey items probing teachers' views of including value-laden topics in biology education applied in the LPA

Item	*Statement*
Values1	I think that topics in biology with connections to social, political or other societal perspectives should be discussed in the biology classroom
Values2	I think that topics of ethical and/or moral nature should be discussed in the biology classroom
Values3	Apart from scientifically accepted explanations and theories regarding biological phenomena I think that misconceptions, opinions and values should be discussed in the biology classroom

Learning Biotechnology Education Teaching Surveys (BELBETS) and Haidar et al. (2014) in the Biotechnology Teaching Survey/Biotechnology Learning Survey (BTS/BLS) and adapted for the current study.

Table 3 presents the 10 items probing the teachers' views of the importance of including specified topics in their biotechnology teaching. The purpose of these items was to investigate whether teachers, or groups of teachers, deemed certain biotechnology topics to be more important to include than other topics, and characteristics of these topics. The items were developed by Kidman (2009) as a part of the Biotechnology Education Learning Biotechnology Education Teaching Surveys (BELBETS) and adapted for the current study.

Table 4 presents the items probing teachers' views of various approaches to teaching science generally, which were used to investigate possible variations in the teachers', or groups of teachers', valuations of the approaches, and characteristics of these approaches. The items were developed by Johnson and McClure (2004) as a part of the Constructivist Learning Environment Survey (CLES) and adapted for the current study.

2.6 Data Analysis

Latent profile analysis (LPA) was applied to identify groups of participants with significantly differing patterns of responses to the value-related items, then non-parametric tests were applied to characterize the differences between them.

LPA enables the classification and grouping of individuals according to patterns of characteristics (latent profiles), often derived from responses to questionnaires (Muthén, 2008). Each group is relatively homogenous in terms of characteristics described by the latent profile indicators (here, those probed by the items described above), or more precisely each

Table 3 Ten items probing teachers' views of the importance of including specific topics in biotechnology education

Item	*Statement*
Topic1	It is important to me to use media articles presenting different perspectives when teaching biotechnology
Topic2	It is important to me to carry out DNA-experiments when teaching biotechnology
Topic3	It is important to me to teach about the harmful effects genetic engineering may have on our environment
Topic4	It is important to me to teach about implications of releasing genetically altered organisms into the environment
Topic5	It is important to me to teach about labelling of genetically modified foods
Topic6	It is important to me to teach about the anxiety many people in society feel towards genetic engineered foods
Topic7	It is important to me to teach about the techniques used to develop different genetically engineered crops (corn, cotton, rice, etc.)
Topic8	It is important to me to teach about different perspectives regarding the use of genetically modified organisms
Topic9	It is important to me to teach about pros and cons of genetically engineered plants in agriculture in different parts of the world
Topic10	It is important to me to teach about the use of gene profiling for genetic fingerprints and paternity testing

Table 4 The ten items probing teachers' views of approaches to teaching science

Item	*Statement*
Teach1	I explain to my students how science can be part of real life
Teach2	My lessons always relate to experiences or questions from the world inside and outside of the school
Teach3	I teach that science has changed over time
Teach4	I teach that science is influenced by people's values and opinions
Teach5	I do not object when a student asks me "why do we have to learn this?"
Teach6	I do not object when a student asks about the way she/he is being taught
Teach7	My students participate in deciding how much time they spend on activities
Teach8	My students participate in deciding which activity (or project) they will do
Teach9	My students discuss among themselves how to solve a certain problem
Teach10	My students help each other by explaining their ideas to each other

group significantly differs from the others. Latent profile, class, and group are sometimes used interchangeably in descriptions of LPA, but there are differences. Latent profiles are individuals' patterns of responses, which are used to assign them to classes, while group is a more general term and not included in standard LPA terminology, unlike latent profile and class. However, for all practical purposes, the LPA term class and group can be treated as synonyms and group is used in discussions of the results as it is a more common term for sets of people with given characteristics.

To identify classes and determine the number providing the best fit to the data (based on the latent profiles derived from responses to the items listed in Table 2), we compared 1-, 2-, and 3-class models. For this, we used three commonly applied tests for evaluating models (Tein et al., 2013), based on the Bayesian information criterion (BIC) (Schwarz, 1978), Vuong-Lo-Mendell-Rubin (LMR) likelihood ratio (Lo et al., 2001), and an entropy index (Celeux & Soromenho, 1996). The BIC is inversely related to a model's fit to the data (although a natural decline with increases in numbers of classes must be accounted for). The LMR test can compare the loglikelihood differences of models, and indicate (for example) if a K_0-class model provides a significantly better fit than a K_{-1}-class model (Tein et al., 2013). The entropy index is based on the uncertainty of classification. For model selection, normalized entropy is commonly used (with a 0–1 range), a higher value indicates a better fit, and a value >0.80 is generally regarded as indicating that the latent classes are highly discriminating (Tein et al., 2013).

To test possible associations between groups of teachers identified by the LPA and characteristics probed by the items on teaching aspects (Tables 3 and 4) and background variables (Table 1), we applied non-parametric testing. Preliminary analysis showed that responses to several items did not meet normality of distribution and homogeneity of variance requirements for parametric tests, as they were negatively skewed, with a skewness of less than -1.0. Therefore, log10-transformation was applied, but normality requirements for parametric tests were still not met. Hence, the significance of differences between groups was assessed using non-parametric Mann–Whitney U and χ^2 tests. In addition, one of the classes identified by the LPA had very low representation, which would have impaired the reliability of parametric testing.

SPSS Statistics Version 27 and Mplus 8.4 software packages were used for all statistical analyses reported here.

3 Results

3.1 Variation in Views on Value-Laden Topics

The LPA identified two groups of teachers: one favoring inclusion of value-laden topics in their teaching and another (smaller group) opposed to it. Standard errors and Cohen's *d*, entropy, BIC, and LMR coefficient values demonstrating the significance of differences in the groups' scores for the items included in the LPA are presented in Tables 5 and 6.

As demonstrated by the Cohen's *d*, entropy, and BIC values presented in Tables 5 and 6, responses of the classes identified by both the two- and three-class models significantly differed, indicating a high degree of separation among them. However, the LMR test indicated that the two-class model was significantly superior to the one-class model ($p=0.046$), while there was a non-significant difference in goodness of fit between the 2- and 3-class models ($p=0.490$). Classes of the two-class solution included 9 and 122 participants, while there were 3, 25, and 103 participants in classes identified by the 3-class model. As the 2-class solution was preferable according to the LMR-test, and the 3-class solution gave rise to an extremely small (potentially artifactual) group with just three respondents, further analysis presented here is based on the 2-class solution. Thus, in summary, the teachers could be divided into two groups with significantly differing latent profiles (and hence patterns of responses to the items regarding inclusion of values).

Mean scores of responses to items regarding inclusion of value-laden topics in biology education (Table 2) of the larger group ranged from + 1.65 to + 1.85, close to the maximum + 2.0 (strongly agree), while mean responses of the smaller group ranged from − 0.45 to − 0.23 (Table 5). Thus, the larger group strongly favored inclusion of such topics, while the smaller group slightly opposed it. Thus, we designated these groups "pro-value inclusion" and "value-sceptical," respectively.

3.2 Teachers' Characteristics Based on Aspects of Teaching

In the next step, we analyzed potential differences between the two identified groups and views regarding both the importance of specific biotechnology content and general

Table 5 Means, standard errors, and *t*-values of scores for items probing views regarding inclusion value-laden topics (Table 2) of teachers assigned to classes identified by the 1-, 2-, and 3-class models

	Item	Mean	SE	t						
1-class model	Values1	1.53	0.07	21.01						
	Values2	1.69	0.06	26.78						
	Values3	1.49	0.07	20.40						
	Item	Mean	SE	t	Mean	SE	t			
2-class model*	Values1	− 0.45	0.46	− 0.99	1.68	0.05	32.94			
	Values2	− 0.45	0.34	− 1.32	1.84	0.03	54.21			
	Values3	− 0.23	0.41	− 0.57	1.62	0.06	27.37			
	Item	Mean	SE	t	Mean	SE	t	Mean	SE	t
3-class model	Values1	− 1.00	0.82	− 1.23	0.84	0.17	5.03	1.78	0.05	33.53
	Values2	− 1.67	0.27	− 6.13	0.80	0.08	10.00	2.00	n/a	n/a
	Values3	− 1.33	0.54	− 2.45	0.84	0.16	5.35	1.73	0.06	31.42

*Preferred model

Table 6 Fit statistics, and separation of identified classes, of the 1-, 2-, and 3-class LPA models, based on Cohen's *d*, entropy, Bayesian information criterion, and Vuong-Lo-Mendell-Rubin likelihood ratio scores for items probing the teachers' views of including value-laden topics (Table 2)

	Item				Entropy	BIC	LMR	Class count
1-class model	Values1				n/a	962.54		n = 131
	Values2						n/a	
	Values3							
	Item	Cohen's d			Entropy	BIC	LMR 2–1	Class count
2-class model*	Values1	2.55			0.996	792.25		$n_1 = 9$
	Values2	3.16					p = 0.046	$n_2 = 122$
	Values3	2.21						
	Item	Cohen's d 3–2	Cohen's d 3–1	Cohen's d 2–1	Entropy	BIC	LMR 3–2	Class count
3-class model	Values1	1.12	3.33	2.20	1.000	658.61		$n_1 = 3$
	Values2	1.66	5.07	3.41			p = 0.490	$n_2 = 25$ $n_3 = 103$
	Values3	1.06	3.67	2.60				

*Preferred model

approaches to teaching science. Responses to seven items regarding important biotechnology content with substantial value aspects significantly differed between the two groups, but not responses to the other three (topics 2, 7, and 10; Table 3), which are less value-laden (Table 7). Moreover, inclusion of these topics was more important to the pro-value inclusion teachers than the value-sceptical group.

This clearly indicates that the more sceptical teachers were less likely to include value-laden topics in their teaching of biotechnology. In addition, responses of the two groups did not significantly differ to any of the items listed in Table 4 concerning teaching approaches, except teach4: *I teach that science is influenced by people's values and opinions* the only one that specifically focused on values. In summary, the more sceptical group were less likely to include this idea in their teaching, but in other respects the two groups' approaches to teaching science seemed very similar (Table 8).

3.3 Associations Between Teachers' Values and Potential Explanatory Variables

The last findings reported here concern associations between the teachers' latent profiles and the following potential explanatory variables: school type (private or municipal), educational program (natural science or natural resource use), gender (male or female), formal teaching certification (yes or no), and years of teaching experience (< 5 years to > 25 years, in 5-year increments). χ^{2-}tests detected no significant association between teachers' views of including values (pro or sceptical) and school type ($\chi^2 = 0.85$, $p = 0.66$), program ($\chi^2 = 0.74$, $p = 0.69$), or gender ($\chi^2 = 0.457$, $p = 0.80$). In addition, no significant association between the groups and formal certification to teach biology at the secondary school level (teacher certification) was detected by Fisher's exact test ($p = 1.00$, two-sided; $p = 0.41$, one-sided). However, the sceptical teachers had significantly more years of teaching experience than the pro-value inclusion group (M = 4.11, SD = 2.03, and M = 3.07, SD = 1.72, respectively; Mann–Whitney $U = 271.00$, $z = -2.573$, $p = 0.010$). Thus, more experienced teachers had more sceptical views of including value-laden topics than less experienced teachers.

Table 7 Means, standard deviations, medians, *U*-statistics, *Z*-tests, and significance of differences based on Mann–Whitney *U* testing between groups identified by the LPA in responses to items regarding inclusion of specific topics in biotechnology teaching

Item	*Pro-value inclusion (n = 122)*		*Sceptical (n = 9)*				
	M (SD)	*Mdn*	*M (SD)*	*Mdn*	*U*	*Z*	*p*
Topic1: *It is important to me to use media articles presenting different perspectives when teaching biotechnology*	1.30 (0.85)	2	0.33 (1.66)	0	340.00	−2.07	0.038*
Topic2: *It is important to me to carry out DNA-experiments when teaching* biotechnology	0.59 (1.24)	1	0.11 (1.36)	0	416.00	−1.25	0.212
Topic3: *It is important to me to teach about the harmful effects genetic* engineering *may have on our environment*	1.10 (0.95)	1	0.33 (1.50)	0	310.00	−2.31	0.021*
Topic4: *It is important to me to teach about implications of* releasing *genetically altered organisms into the environment*	1.28 (0.84)	2	0.11 (1.54)	0	245.50	−2.98	0.003*
Topic5: *It is important to me to teach about labelling of* genetically *modified foods*	0.55 (1.21)	1	−0.44 (1.51)	−1	239.50	−2.90	0.004*
Topic6: *It is important to me to teach about the anxiety many* people *in society feel towards genetic engineered foods*	0.96 (1.06)	1	−0.22 (1.34)	−1	173.00	−3.59	0.000**
Topic7: *It is important to me to teach about the techniques used to develop different genetically engineered crops (corn, cotton, rice,* etc.*)*	0.95 (0.95)	1	0.56 (1.74)	0	439.00	−1.05	0.294
Topic8: *It is important to me to teach about different* perspectives *regarding the use of genetically modified organisms*	1.49 (0.72)	2	0.44 (1.59)	0	296.50	−2.62	0.009*
Topic9: *It is important to me to teach about pros and cons of genetically engineered plants in agriculture in different parts of the world*	1.52 (0.65)	2	0.56 (1.51)	1	288.50	−2.70	0.007*
Topic10: *It is* important *to me to teach about the use of gene profiling for genetic fingerprints and paternity testing*	1.04 (0.87)	1	0.44 (1.59)	1	498.50	−0.49	0.627

*Significant difference at the 0.05 probability level

**Significant difference at the 0.01 probability level

Table 8 Means, standard deviations, median, *U*-statistic, *Z*-test, and significance of differences based on Mann–Whitney *U* testing between groups identified by the LPA in responses to items regarding approaches to teaching science

	Pro-value inclusion (n=122)		*Sceptical (n=9)*				
Item	*M (SD)*	*Mdn*	*M (SD)*	*Mdn*	*U*	*Z*	*p*
Teach1: *I explain to my students how science can be part of real life*	1.53 (0.82)	2	1.56 (0.73)	2	474.50	−0.82	0.412
Teach2: *My lessons always relate to experiences or questions from the world inside and outside of the school*	0.56 (1.01)	1	−0.22 (1.09)	0	361.50	−1.79	0.073
Teach3: *I teach that science has changed over time*	1.11 (0.90)	1	0.33 (1.50)	1	420.00	−1.25	0.210
Teach4: *I teach that science is influenced by people's values and opinions*	1.44 (0.66)	2	0.44 (1.13)	1	239.00	−3.13	0.002*
Teach5: *I do not object when a student asks me "why do we have to learn this?"*	1.49 (0.90)	2	1.11 (0.93)	2	463.50	−0.94	0.346
Teach6: *I do not object when a student asks about the way she/he is being taught*	1.77 (0.46)	2	1.33 (0.87)	2	478.50	−0.88	0.380
Teach7: *My students participate in deciding how much time they spend on activities*	−0.22 (1.10)	0	−0.44 (1.01)	-1	413.00	−1.28	0.199
Teach8: *My students participate in deciding which activity (or project) they will do*	−0.30 (1.15)	0	−0.44 (1.33)	-1	424.00	−1.17	0.241
Teach9: *My students discuss among themselves how to solve a certain problem*	1.26 (0.74)	1	1.22 (0.83)	2	505.50	−0.43	0.667
Teach10: *My students help each other by explaining their ideas to each other*	1.25 (0.73)	1	0.78 (0.83)	1	478.50	−0.70	0.484

*Significant difference at the 0.05 probability level

4 Discussion

This study presents results on science teachers' non-epistemic values in science education, particularly biology education. There is increasing interest in teachers' values because they influence teaching practices, perceived relevance of content, and thus students' engagement in science education (Cooper & Loughran, 2020; Kumarassamy & Koh, 2019; Smith & Corrigan, 2020). However, there is little information about the variation in their values and reasons for the variations. We identified two groups of Swedish science teachers with significantly differing latent profiles. One favored, and another smaller group slightly opposed, the inclusion of strongly value-laden topics in biotechnology education, i.e., those with major ethical and societal implications, as well as misconceptions and opinions in science teaching. This has profound theoretical and practical implications, suggesting that the detected variation in teachers' values (and potentially other variations, not explored here, such as religious convictions) may require careful attention in efforts to develop science teaching. Notably, as we only probed views of upper secondary teachers, the possibility that views of including such topics may partly depend on the educational level and students' maturity warrants attention. Exploration of views of teachers of other science subjects (such as physics, chemistry, and geology) may also be illuminating.

Other main findings concern associations between the participants' views of including values and their teaching practices. Those who favored inclusion of values assigned substantially more importance to including specific strongly value-laden topics than the other group. This corroborates previous findings. Prior studies have addressed aspects of the relation between science teachers' values and implementation of values in their classroom practice in more general terms. For example, Kumarassamy and Koh (2019) interviewed teachers in Singapore and New Delhi about infusion of values in science lessons, and Ratcliffe (2012) observed science teaching in England, in efforts to identify aspects of teachers' values in their teaching. Kumarassamy and Koh (2019) found that teachers in both Singapore and New Delhi have positive views on values-infused science lessons. Furthermore, they state that values are infused in their science teaching and that values-infused science lessons generally had a positive influence on students' interest and motivation to study science. Ratcliffe (2007, 2012) reports on the necessity for teachers to reflect on their own values to successfully increase emphasis on values in science classroom practice. Our study extends previous findings by showing that science teachers' values affect both the selection of content and their general approach to teaching science.

In contrast, there was no significant difference between the groups in responses to items concerning inclusion of specific topics in biotechnology education that are not strongly value-laden. Moreover, there was no significant difference in their responses to items concerning science teaching approaches except for one, revealing that teachers who favored inclusion of values were significantly more likely to teach that science is influenced by people's values and opinions.

In summary, the surveyed teachers who favored inclusion of values were more likely to include specific value-laden content and teach that values influence science. There are clear limitations, as we focused on Swedish upper secondary science teachers engaged in biotechnology education, a domain with profound moral and ethical dimensions. Moreover, the findings are based on the teachers' responses to a questionnaire. Thus, further studies in other settings and classroom observations are required to assess their generalizability and validity in practice. Nevertheless, the findings confirm a relation between values, the way they have been investigated in this study, and what science teachers choose to teach as well as how they teach. Thus, this relation strongly influences the science education students are exposed to.

As including strongly value-laden topics and contexts enhances students' interest and motivation to learn science, it is also important to elucidate associations between teachers' values and explanatory factors to aid efforts to improve science education. Here, as already mentioned, we have adopted the definition of non-epistemic values presented by Koster and de Regt (2020, p. 126): "cultural, moral, economic, and political values and also more personal values based on religious commitments, interests, or loyalty to colleagues and sponsors." We recognize that they are rooted in beliefs, which are assumptions people believe to be true about the world based on their knowledge and experience (Pajares, 1992); they have long-term stability, guide behavior, and strongly influence decision-making (Halstead, 1996; Schwartz, 2012). Thus, every science teacher has a set of values rooted not only in their professional educational setting, but also their previous socio-cultural and educational milieus, which affect their teaching, behavior, and decision-making (Fig. 3).

The applied theoretical framework supports the evidence to justify the investigated values as being non-epistemic. To validate this, further studies should explore reasons behind teachers' statements. With this, we do not claim that there are also epistemic values in motion. Consequently, we cannot be sure about all causal factors behind the results presented here, but the non-epistemic values of the two groups of teachers are clearly related with their teaching. Teachers that favor inclusion of topics with strong moral and ethical dimensions are more likely to include such content, and consider multiple opinions, in their science teaching than more sceptical teachers. These patterns (and their pedagogic effects) will likely have long-term stability, due to values' inherent properties. Moreover, science is increasingly regarded as a value-laden enterprise, rather than being value-free, as portrayed in historical ideals (Sutrop, 2015), so scientists are inevitably influenced by the values that permeate the research domains in which they work and socio-cultural milieu in which they live. An important context for science education on all levels, where scientists and science teachers interact, is pre-service teacher training, which is permeated by scientists' epistemic and non-epistemic values (directly and/or indirectly), thereby potentially affecting values of the next generation of teachers related to both science education and

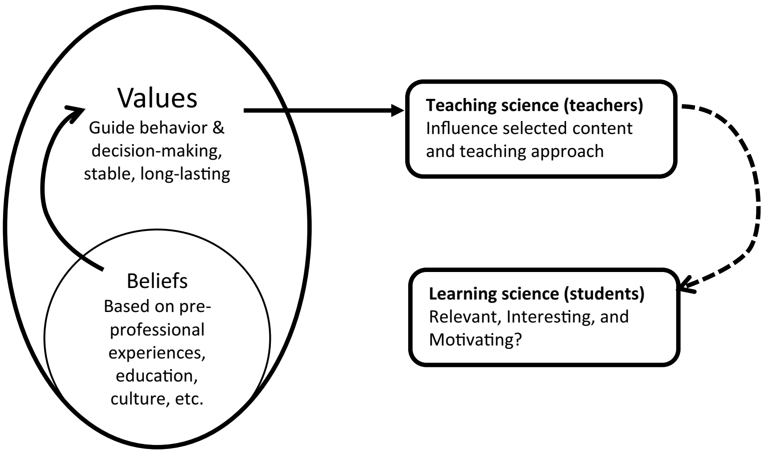

Fig. 3 Graphical illustration of the alignment between the theoretical framework and results of this study (adapted from Fig. 1)

science per se. Scientists also play an important role in science teacher training, highlighting the importance of learning more about their values. Substantial literature on students' valuations of science and scientists corroborates the importance of science and scientists in science education (Bennett & Hogarth, 2009; Finson, 2002; Woods-Townsend et al., 2016). Surprisingly, however, effects of scientists' values on science education do not seem to have been explored yet, despite needs to understand them to enhance science education, scientific literacy, and the general public's understanding of science.

The other main findings of this study concern potential explanatory factors, thereby extending previous findings that teachers' values, and thus their teaching of science, are rooted in individual experience (Simon & Connolly, 2020). To explore these factors, we tested associations between the teachers' responses and several background variables. Four tested factors had no significant associations. Those were secondary education program, certification for teaching biology at this level, type of school (private or municipal), and gender. However, teaching experience was negatively correlated with the teachers' likelihood to favor inclusion of values. According to Simon and Conolly (2020), science teachers' values stem from their previous experiences during their own pre-professional education and pre-service practice. Perhaps teachers who received their pre-service education longer ago are less likely to have been encouraged to include value-laden topics. Their values will at least partly depend on when and how they were shaped. These relationships warrant closer attention.

As already mentioned, rapid advances in science are generating technologies that increasingly permeate every aspect of our lives, raising increasingly complex moral and ethical issues (Chowdhury, 2016). Education policy-makers have reacted to these changes by implementing curricula that include value-laden topics and increasing their inclusion and consideration in pre-service teacher education (France, 2007). Thus, beliefs and values of the more experienced participants may have been rooted in those prevailing when science was regarded as less value-laden than it is now, during their personal educational experience and pre-service teacher education. As individuals' non-epistemic values are generally stable and long-lasting, teachers' views may also remain largely intact over time. However, further studies in other settings are clearly required to draw general conclusions and deepen understanding of science teachers' values, factors that shape them, and their pedagogic effects.

In conclusion, due to their strong connections with selected topics and teaching approaches, teachers' non-epistemic values play a key role to help students to understand the relevance of science education. The results in the study cannot conclude in all what affect teachers' selection of topics and approaches to teaching, but there is a strong indication that teachers' non-epistemic values play an important part. Other values and factors are also important to further investigate, to explore effects of other kinds of values, such as teachers' religious and ethical stances, or instrumental reasons behind values imposed by profession, as well as further analysis of quality approaches (such as discussion of media articles) to be able to develop practice based on research evidence. The finding that teaching experience was negatively linked to participants' likelihood of favoring the inclusion of value-laden topics in their teaching was unexpected but supports the importance of long-term understanding of how science teachers' values and beliefs are formed. As teachers selected topics and teaching approaches as well as teaching experience (temporal aspect) are shown to be grouped, it is of importance to further investigate underlying causes to science teachers' expressed values and ways that they might vary temporally but also ways that they cluster. In a broader view, other rapidly growing circumstances need close attention in the research of values in science education, notably for instance the possible effects of information and disinformation movements in society at large.

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Data Availability The data that support the findings of this study are available from the authors upon request.

Declarations

Conflict of Interest The authors declare no competing interests.

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