Routledge
Taylor & Francis Group

Journal of Biological Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rjbe20

Make biology relevant again! Pre-service teachers' views on the relevance of biology education This paper was presented at the ERIDOB conference 2020

Justus Mutanen & Anna Uitto

To cite this article: Justus Mutanen & Anna Uitto (2020) Make biology relevant again! Pre-service teachers' views on the relevance of biology education This paper was presented at the ERIDOB conference 2020, Journal of Biological Education, 54:2, 202-212, DOI: 10.1080/00219266.2020.1739423

To link to this article: https://doi.org/10.1080/00219266.2020.1739423

Published online: 13 Mar 2020.

Submit your article to this journal

Article views: 198

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=rjbe20

JOURNAL OF BIOLOGICAL EDUCATION
2020, VOL. 54, NO. 2, 202–212
https://doi.org/10.1080/00219266.2020.1739423

Routledge
Taylor & Francis Group

Check for updates

Make biology relevant again! Pre-service teachers' views on the relevance of biology education

This paper was presented at the ERIDOB conference 2020

Justus Mutanen[a] and Anna Uitto[b]

[a]The Faculty of Biological and Environmental Sciences, The University of Helsinki; [b]The Faculty of Educational Sciences, University of Helsinki, Helsinki, Finland

ABSTRACT

Biology education should be relevant to young students so that they can become interested in biology and understand biological topics in their everyday and vocational lives. We conducted interviews and collected mind maps to examine Finnish pre-service biology teachers' (N = 16) views on the relevance of biology education. Furthermore, we analysed Finnish secondary school biology curricula, which were compared with the pre-service teachers' answers. We classified the views on relevance into nine main categories using grounded theory as the methodological frame of reference. Pre-service teachers emphasised the relevance of biology to the student's own life, whereas scientific practices and the nature of science were expressed in secondary school curricula more often. Novice pre-service teachers put more value on general knowledge, while more experienced pre-service teachers were more likely to mention sustainable futures and societal aspects in their reasoning. Based on the results, we identified two stages in the development of the views. This study suggests that pedagogical studies, teaching experience and teacher training have an impact on the pre-service teachers' views about the relevance of biology education. Moreover, we could find differences between curricula and pre-service teachers' views, especially regarding scientific practices and the role of the nature of science in biology education.

KEYWORDS

Biology teacher education; relevance; professional development; curriculum; scientific literacy

Introduction

During the past few decades, a growing crisis in the field of science education in western countries has emerged (Treagust and Tsui 2014). There has been a shortage of people in the professional workforce and many science-based workplaces are moving to developing countries (Tytler 2007). Concurrently, young students in western countries do not consider science to be meaningful to them (Sjøberg and Schreiner 2010). One of the possible reasons for the declining interest and achievement in science is that young students consider science education to be irrelevant to them (Schreiner and Sjøberg 2004). To encourage students to develop positive views about science and biology, science education should also be relevant to students at the individual level. In addition, it is important that science education is relevant to the society as well as the future vocational life of the students (Cleaves 2005; Hofstein, Eilks, and Bybee 2011; Osborne, Simon, and Collins 2003; Uitto and Kärnä 2014; Uitto, Kärnä, and Hakonen 2013). It is also important that societal aspects are covered in science education, so

CONTACT Justus Mutanen justus.mutanen@helsinki.fi

© 2020 Royal Society of Biology

that the education is relevant for the future vocational life of the students (Hofstein, Eilks, and Bybee 2011; Osborne, Simon, and Collins 2003).

Even though the concept of relevance is often applied to educational contexts, it has been defined in multiple ways (Newton 1988; Stuckey et al. 2013). In some cases, researchers do not draw a clear line between relevance and interest and/or motivation (Holbrook 2008; Levitt 2001; Simon and Amos 2011; Sjøberg and Schreiner 2010). However, according to Stuckey et al. (2013), it is obvious that 'relevant' is not synonymous with 'interesting', because science content can be relevant to students even if they are not interested in it. For example, it may just be relevant for their future career. There are numerous studies on interest (see Krapp and Prenzel (2011)) and attitudes (see Osborne, Simon, and Collins (2003)) in the field of science education research. If school science is interesting, it will have a positive effect on students' attitudes and make learning science easier. However, school science should not only be interesting but also meaningful and relevant to young students (Stuckey et al. 2013). Therefore, to get a comprehensive view on the relevance of school science, focusing on interest, passion, or attitudes only does not reveal the whole picture. Choosing relevance as the main theme of the theoretical framework enables us to get a more holistic insight into science education.

Stuckey et al. (2013) formulated a theoretical framework for the relevance of science education. In their framework, the relevance of science education consists of three levels of individual, societal and vocational relevance. In addition, the framework contains a temporal component and an intrinsic-extrinsic component. The authors argue that all three levels (individual, societal and vocational) have to be present in science education to make it more relevant. In addition, Aikenhead (2006) has explored who defines the relevance of science education. Traditionally, academic scholars have defined the relevance of science education. However, there are numerous other groups trying to impact the school science curriculum, e.g. the media, health experts and students themselves (Aikenhead 2006). All of those groups affect how the relevance of science education is defined.

The concept of relevant science education is also related to the concept of scientific literacy (SL), i.e. science education should prepare students for not only everyday life, but also for their future careers and participation in society (Cleaves 2005; Hofstein and Kesner 2006; Osborne, Simon, and Collins 2003). Roberts (2007) has also covered the topic of relevant or meaningful science education with his two visions for SL. According to vision I, science education is relevant because it enables development of scientific thinking skills and practices as well as promoting the education of future scientists. However, according to vision II, science education should also be relevant because students need scientific skills in their everyday life and societal life (Roberts 2007; Roberts and Bybee 2014). It is obvious that developing scientific literacy is also a central component in relevant science education.

To make science education relevant to the students, science teachers should have a clear vision about the relevance of science education. However, there is little research about what kinds of views science teachers have, and how these views develop when teachers obtain more experience of teaching, and become more proficient teachers (Berliner 1988). Furthermore, the role of teacher education in the development of views on relevance is not yet fully understood. This knowledge is needed for science teacher education development, but also to support curriculum development and in-service training for science teachers. In addition, instructional methods and approaches to teaching have a central role in making science education more interesting and developing students' attitudes (Juuti et al. 2010; Lavonen et al. 2008; Uitto, Kärnä, and Hakonen 2013). It is also evident that teaching methods may have an effect on the experienced relevance of science education.

In this study, the theoretical framework of relevance in science education has been applied to biology education, as biology education is an essential part of science education. However, there are some special characteristics in biology education compared with general science education (such as environmental aspects); therefore it is useful to take a look into the relevance of biology education

in detail. To get more knowledge about pre-service teachers' views on the relevance of biology education, we formulated the main research questions of this study:

(1) How do pre-service biology teachers perceive the relevance of biology education?
(2) Do pre-service teachers' perceptions of relevance correspond to or differ from the relevance of biology education as it is outlined in national curricula?
(3) Does teaching experience have an impact on pre-service biology teachers' views on the relevance of biology education?

Research design and methodology

Research subjects

In this study, the participants were Finnish pre-service biology teachers that took part in an optional biology didactics course called 'The introduction to teaching biology'. The course was open to all pre-service biology teachers. The pre-service biology teachers were asked to participate in an interview at the beginning of the course (as a voluntary task for the students). We selected twelve female and four male pre-service teachers to be interviewed (the ratio represents the gender ratio of biology teachers in Finland). To get a comprehensive view, we selected both beginner and more experienced students for this study. The students had completed 1–9 years of university studies and seven students had already completed their teachers' pedagogical studies. Seven students studied biology as their major subject while nine students studied biology as their minor subject. Half of the students were bachelor students while the rest were Masters students.

Data collection

We conducted in-depth, semi-structured interviews to examine pre-service teachers' views on the relevance of biology education. There were two parts in the interview: First, the interviewees were asked to draw a mind map about '*the relevance of biology education*'. The participants were given a sheet of A4 size paper and no time limit to complete their mind map (Figure 1). Two further questions were given to help create the mind map: '*What is the meaning of teaching biology?*' and '*Why is it useful to teach biology at school?*'.

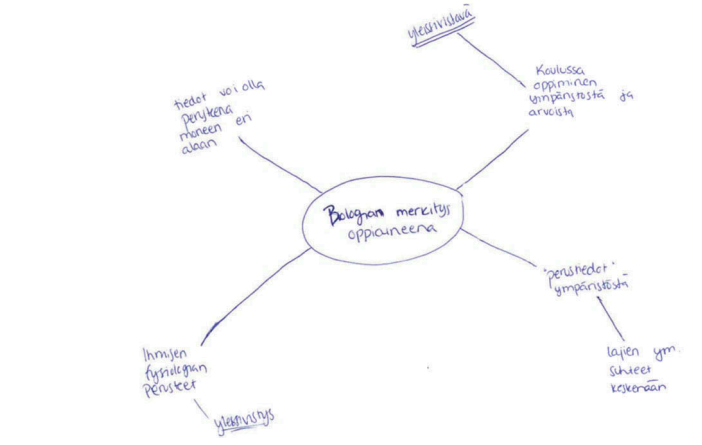
Students' background information was also collected (age, gender, study history, work experience, the phase of studies, major subject). The mind map was used as a starting point for the semi-structured interview, and the interviewees were asked about 1) their views on the relevance of biology education, and 2) what kind of teaching approaches they would use to make biology education more relevant. The following questions were used as a basis of the analysis:

- Why do you think biology is relevant as a school subject?
- Why do you think biology is relevant to the students?
- What would happen if biology wasn't taught at school?

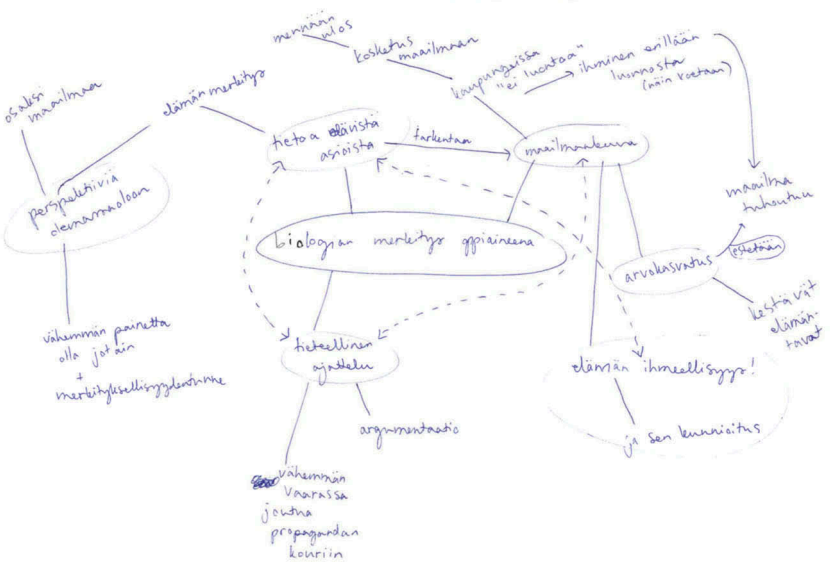
In addition, Finnish secondary school biology curricula (National Core Curriculum for Basic Education 2014 and National Core Curriculum for General Upper Secondary Schools 2015 – produced by The Finnish National Board of Education (2015a, 2015b respectively)) were analysed and compared with students' answers.

Data analysis

We applied a grounded theory approach to data analysis. The analysis of the data started when we conducted the interviews. During the process, memos about the interviews, the transcriptions and



a)



b)

Figure 1. Examples of pre-service biology teachers' mind maps about the relevance of biology education. Mind map (a) is drawn by a bachelor student with no pedagogical studies and no teaching experience, while mind map (b) is drawn by a Masters student who had completed the teachers' pedagogical studies and had some teaching experience.

the coding process were made. Further interviews were conducted during the years 2017 and 2018 until new data did not provide new insights into analysis, hence the data was saturated (Bryant and Charmaz 2007; Corbin and Strauss 1990).

The interviews were transcribed and read repeatedly before coding. Using the Atlas.ti software (by ATLAS.ti Scientific Software Development GmbH, version 8.2), we classified the data by open coding (Cohen, Manion, and Morrison 2013; Corbin and Strauss 1990) to identify the units of relevance in the interviews. In addition to the transcripts, mind maps were used during the coding process to achieve a reliable classification. The open coding protocol was repeated to check the trustworthiness of the analysis. Codes with shared attributes were grouped into bigger categories by

the axial coding process, where the core themes and connections were identified. Finally, similar categories were grouped into core categories (selective coding) and four core themes emerged.

Based on the analysis, we calculated the total amount of quotations in the interviews. We compared different background factors (gender, major subject, the phase of studies, teaching experience, and the phase of pedagogical studies) with the amount of the quotations in each core category. Non-parametric Mann-Whitney U-tests were carried out to establish statistical differences.

Results

Pre-service teachers' views on the relevance of biology education

Based on the iterative analysis distinctive to a grounded theory approach, we were able to categorise the views and curriculum rationales into four core themes and nine core categories (Table 1).

There were neither statistically significant differences between genders nor pre-service teachers with different major subjects. However, pre-service teachers who already had completed their teachers' pedagogical studies gave less emphasis on the general knowledge, and more emphasis on personal curiosity instead (Figure 2).

In addition, pre-service teachers with more teaching experience (e.g. as a substitute teacher) gave more emphasis on relevance for an individual and less emphasis on general knowledge (Figure 3).

In this study, pre-service teachers emphasised the relevance of biology for everyday life, whereas issues related to the nature of science (NOS) were expressed in biology curricula more often. Novice pre-service teachers put more value on general content knowledge, while experienced pre-service teachers were more likely to mention the sustainable future and societal aspects in their reasoning. Based on the results, we identified two phases in the development of the views:

- Developing. Novice (freshman and sophomore) pre-service teachers were more likely to highlight the meaning of general content knowledge, and did not connect relevance to societal or vocational aspects. These pre-service teachers gave typically concrete examples about relevance, which were often connected to everyday life. In addition, they put value on general knowledge without connecting it to a specific context, such as societal participation or vocational life. The following two excerpts (pre-service teachers A and B) represent developing views.

Interviewer: 'What do you think, what would happen if biology wasn't taught at school?'

Pre-service teacher A: 'I think it is very general knowledge, and if there is nothing that would replace it [biology], many people would lack important knowledge'

Interviewer: 'What do you think, what would happen if biology wasn't taught at school?'

Pre-service teacher B: 'I don't know if it is important to know different species, but I think it is [important] that you can know that tree is a tree and a flower is a flower, and what is the difference between them.'

- Developed. The most experienced pre-service teachers expressed a wide range of different reasons. These pre-service teachers also included philosophical aspects and building students' world view perceptions in their reasoning, as well as societal and vocational perspectives. They also took account into the sustainable future and societal issues. The following two excerpts (pre-service teachers C and D) represent developed views.

Interviewer: 'What do you think, what would happen if biology wasn't taught at school?'

Table 1. The classification of pre-service teachers' views on the relevance of biology education.

Core themes	Core categories	Examples	Quotations
Relevance for an individual	1. Everyday life	- Practical everyday skills (health, food) - Learning to understand oneself and others	'Should you go to a forest, you would know what kinds of berries you can pick.' 'You can identify when food goes bad and you know how to preserve it and you don't get food poisoning.'
	2. Student's future	- Future studies and career choice - Earning money - The big and small decisions of life	'Of course if you choose a career where biology is needed, such as a doctor or a vet.' "If you would like to go to a medical school or study chemistry or whatever."
	3. World view perceptions	- The big questions - Science and religion - Ethical questions - Personal connection to the nature	'Philosophical questions about the world, "Who are we? Where have we come from?" – Ancient, primitive questions to which answers can be found in biology.'
	4. Personal curiosity	- Need to understand - General interest in nature	'Maybe we have some kind of need to just understand how things in our surroundings work, and how the universe functions.'
Relevance for society	5. Society and vocations	- Needs of workplaces - Progress of science and technology in society	'There would be new workers – - and we can support those workplaces.' 'Biology is a discipline which brings new responsibility, new findings and is connected to the progress of the society.'
	6. Democracy and decision-making	- Decision-making and negotiating - Discussion in society - Understanding media	'You can be critical to the media.' 'People would vote – - in a responsible way.' 'I had mentioned gene technology and protecting environment – - you can discuss about those issues.'
Relevance for science and knowledge	7. General knowledge	- Subject-specific knowledge and facts - Connections between science disciplines	'To know how a cell works and – - how plants grow and develop.' 'It is important to know how living organisms acquire their matter – what is food such as bread and strawberries and plants.'
	8. Scientific practices and the nature of science	- Thinking skills - Research skills - Critical thinking - The nature of science	'In general, it is more difficult to understand what [kind of claim] is a fact and what is not.' 'It is important to understand the scientific method, understand what real science is and what is fake science and if emotions or reasoning affect your results.'
Relevance for the sustainable future	9. The sustainable future	- Sustainable values - Appreciation of nature - Sustainable actions	'Environment will not be destroyed if people take care of it – - and we can avoid the worst catastrophes.' 'You would probably consider reproducing if you think that the world exists when you have offspring.'

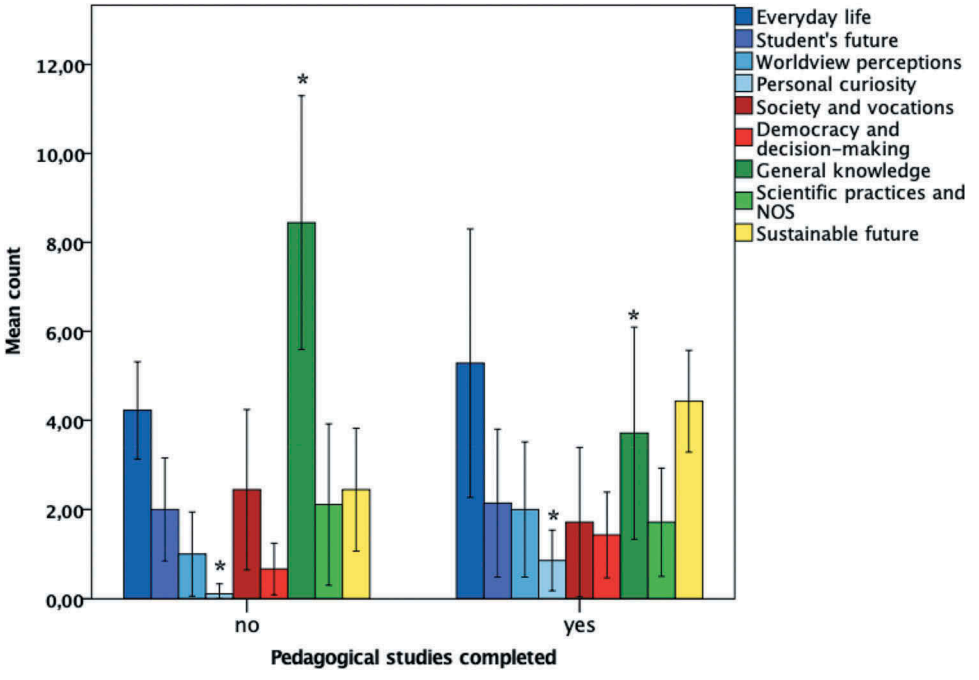


Figure 2. Mean count and standard deviation (±2 SE) of quotations in the pre-service teachers' (N = 16) interviews representing different core categories. Pre-service teachers with no pedagogical studies gave more emphasis on general knowledge, and less emphasis on personal curiosity (* $p < 0.05$).

Pre-service teacher C: 'There would be more division between people and the nature – - and people would not understand medicine or environmental change – - it could confine topics of interest or what are perceived valuable – - and people would become less empathetic.'

Interviewer: 'What do you think, what would happen if biology wasn't taught at school?'

Pre-service teacher D: 'The first issues that come into my mind, are applications of biology, for instance in different innovations. Or in the vocational life, it would be difficult to find skilled labour to the workplaces where biology is needed.'

Pre-service teachers' perceptions of the relevance of biology education with regards to the Finnish secondary school curricula

To figure out the pre-service teachers' perceptions on the relevance of biology education, an overall comparison between participants' emphasis of core categories in biology education and the emphasis of the written lower and secondary school core curricula was carried out. We used the theoretical framework that emerged from the data and used it to analyse Finnish secondary school curricula (lower and upper secondary school). We selected only the general description of biology as a school subject as well as the aims of biology as a school subject for the analysis. Based on the analysis, we calculated the total amount of quotations in the interviews and the curricula and the proportion of each core themes. We found that pre-service teachers gave more importance to the core categories relating to the relevance for an individual (see also Tables 1 and 2), whereas there was more emphasis on relevance for science and knowledge in the curricula. The proportions of each core theme are displayed in Figure 4.

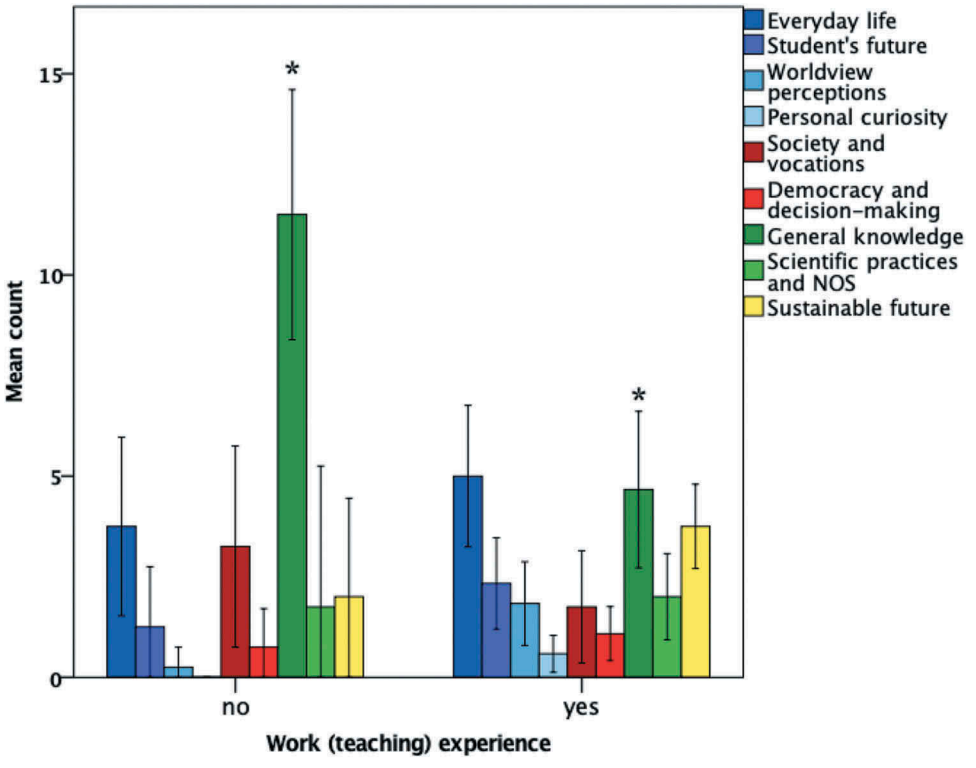


Figure 3. Mean count and standard deviation (±2 SE) of quotations in the pre-service teachers' interviews (N = 16) representing different core categories. Pre-service teachers with work (teaching) experience gave less emphasis on relevance for general knowledge ($p < 0.05$).

Discussion

This study suggests that formal teacher education, pedagogical studies and teacher training have an impact on pre-service teachers' views on the relevance of biology education. We found differences between the objectives of the biology curricula and pre-service teachers' views, especially concerning NOS education. We also identified that novice pre-service teachers had more general, subject-centred views on the relevance of biology education. According to Berliner (1988), at the beginning of their career (and during their studies) teachers are *novices* with little experience, inflexible teaching and teachers follow the instructions very carefully, and their ideas about the subject may be heavily influenced by university science. However, *advanced beginners* start to combine theoretical thinking and teaching experience, but it is still challenging to focus on the main goals of education (Berliner 1988; Dreyfus & Dreyfus 1986). In this study, we would suggest that the transition from a novice pre-service teacher to an advanced beginner might already happen during the teacher's pedagogical studies, especially during practical teacher training.

In addition, pre-service teachers put more emphasis on the relevance for an individual, such as everyday life issues, compared with the secondary school curricula. It is quite obvious that future teachers use everyday life in their reasoning about why biology is a relevant school subject. In addition, pre-service teachers typically mentioned concrete examples on the relevance of biology education, and many of those examples are connected to everyday life, while concrete examples on societal relevance are harder to think of. There was more emphasis on relevance for science and knowledge in the secondary school curricula (especially scientific practices and the nature of science). This can be partly explained by the fact that the Finnish secondary school curricula are content-centred and the relevance of the topics is not covered in the curricula. Furthermore, we

Table 2. Comparison of the core themes of this study with the relevance of science education covered by Stuckey et al. (2013) and Aikenhead (2006).

This study	Stuckey et al. (2013).	Aikenhead (2006).
Relevance for an individual	**Individual relevance**	**Need-to-know science**
- Everyday life	**Vocational relevance**	- Everyday life
- Student's future	- Student's vocational life	**Have-cause-to-know science**
- Worldview perceptions ('weltanschauung')		- Healthy decisions
- Personal curiosity		**Personal-curiosity science**
Relevance for society	**Societal relevance**	**Enticed-to-know science**
- Society and vocation	**Vocational relevance**	- Understanding media
- Democracy and decision-making	- Vocations in a society	**Have-cause-to-know science**
		- Decision-making
		Functional science
		- Working-life skills
Relevance for science and knowledge		**Wish-they-knew science**
- General knowledge		- Future studies, academic science
- Scientific practices & the nature of science		
Relevance for the sustainable future	**Societal relevance**	
- The sustainable future		
		Science-as-culture

could see that there is more emphasis on societal issues in the upper secondary school curriculum. In science education, societal issues should gain more emphasis when the students get older and the meaning of individual relevance decreases (Stuckey et al. 2013).

Based on previous studies about the relevance of science education, Stuckey et al. (2013) synthesised a theoretical framework, in which 'relevance' consists of a temporal component, an intrinsic-extrinsic component, and dimensions of individual, societal and vocational relevance. They claim that relevant science education has positive effects on the life of a student, but this effect might be connected to the individual interests of a student or to the societal or vocational needs of a society. Furthermore, Aikenhead has also covered the relevance of science education in his texts, especially through curriculum evolvement. He claims that traditionally, academic scholars have defined the relevance of science education. In addition, there are other groups trying to affect the school science curriculum. For example, ordinary citizens face science-related problems and issues in their everyday lives; employers need skilled labour with competent working-life skills; and experts (such as health experts) are concerned with the general public (Aikenhead 2006, 2007).

Compared with other studies, such as Stuckey et al. (2013), our results show that biology education is also important in building students' world view perceptions. In addition, sustainability education is a central part of biology education. Stuckey et al. (2013) consider sustainability issues to be societal in nature. Moreover, Aikenhead's (2006) 'have-cause-to-know science' is also human-centred in nature and is connected to societal aspects. However, in biology education, the well-being of nature (apart from the human society) is a central part in defining the meaning or relevance of biology as a school subject. This was also something that many pre-service teachers emphasised in this study (e.g. '*it is important to – - understand the importance of the nature, and to appreciate it in itself*').

Moreover, the aspect of worldview perceptions ('weltanschauung') has been neglected in the studies about the relevance of science education. According to the pre-service teachers, affecting students' worldview perceptions is an important part of biology education. The similar viewpoint can also be seen in Finnish secondary school curricula, e.g.: '*The instruction increases understanding of the significance of biology as a part of the construction of the students' scientific worldview*' (The Finnish National Board of Education 2015b). We have compared our framework with Stuckey et al.'s (2013) and Aikenhead's (2006) framework in Table 2.

Based on these preliminary results, we would suggest that the concept of relevant biology education should also be covered in biology teacher education. This study suggests that teacher training and pedagogical studies have an effect on pre-service teachers' thinking and their ideas

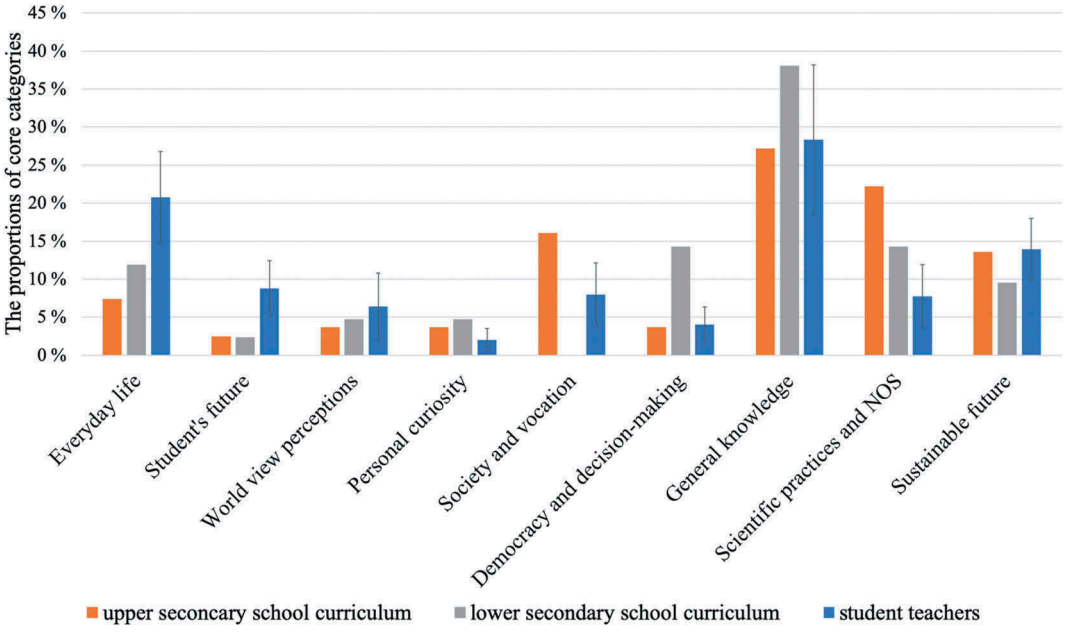


Figure 4. The proportion of core categories mentioned in the biology curricula and in the interviews of pre-service biology teachers' when reflecting the relevance of biology education. Error bars = ± 2 SE.

about the relevance and meaning of biology education. To bring pre-service teachers' views closer to the aims of biology curricula, the issue of relevance might be useful to be covered in teacher education programmes as well. In particular, the biggest differences between pre-service teachers and curricula were on the category of scientific practices and the nature of science. In the curricula, scientific skills and practices are emphasised, whereas pre-service teachers put little emphasis on those issues. It might be useful to cover the topic of the nature of science more thoroughly in biology teacher education as well.

To obtain a better understanding of pre-service and in-service teachers' views on the relevance of science education, more comprehensive studies should be carried out. It would be useful to research experienced biology teachers and compare their ideas about the relevance of biology education with the pre-service teachers' ideas. It would also be useful to carry out a longitudinal study to identify the central events that affect future science teachers' views on the meaning and relevance of their school subject.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Aikenhead, G. S. 2006. *Science Education for Everyday Life: Evidence-based Practice*. New York, NY: Teachers College Press.

Aikenhead, G. S. 2007. "Humanistic Perspectives in the Science Curriculum." In *Handbook of Research on Science Education*, edited by S. K. Abell and N. G. Lederman, 881–910, Mahwah, NJ: Lawrence Erlbaum Associates.

Berliner, D. C. (1988). *The development of expertise in pedagogy*. Charles W. Hunt Memorial Lecture. New Orleans, LA: AACTE.

Bryant, A., & Charmaz, K. 2007. *The SAGE handbook of grounded theory*. London: Sage Publications.

Cleaves, A. 2005. "The Formation of Science Choices in Secondary School." *International Journal of Science Education* 27 (4): 471–486. doi:10.1080/0950069042000323746.
Cohen, L., L. Manion, and K. Morrison. 2013. *Research Methods in Education*. New York: Routledge.
Corbin, J. M., and A. Strauss. 1990. "Grounded Theory Research: Procedures, Canons, and Evaluative Criteria." *Qualitative Sociology* 13 (1): 3–21. doi:10.1007/BF00988593.
Dreyfus, H., & Dreyfus, S. (1986). *Mind over machine: the power of human intuitive expertise in the era of the computer*. New York: Free Press.
The Finnish National Board of Education. 2015a. *National Core Curriculum for Basic Education 2014, Publications/ Finnish National Board of Education*. Helsinki: Finnish National Board of Education.
The Finnish National Board of Education. 2015b. *National Core Curriculum for General Upper Secondary Schools 2015: National Core Curriculum for General Upper Secondary Education Intended for Young People, Publications/ Finnish National Board of Education*. Helsinki: Finnish National Board of Education.
Hofstein, A., I. Eilks, and R. Bybee. 2011. "Societal Issues and Their Importance for Contemporary Science Education-a Pedagogical Justification and the State-of-the-Art in Israel, Germany, and the USA." *International Journal of Science and Mathematics Education* 9 (6): 1459–1483. doi:10.1007/s10763-010-9273-9.
Hofstein, A., and M. Kesner. 2006. "Industrial Chemistry and School Chemistry: Making Chemistry Studies More Relevant." *International Journal of Science Education* 28 (9): 1017–1039. doi:10.1080/09500690600702504.
Holbrook, J. 2008. "Introduction to the Special Issue of Science Education International Devoted to PARSEL." *Science Education International* 19 (3): 257–266.
Juuti, K., J. Lavonen, A. Uitto, R. Byman, and V. Meisalo. 2010. "Science Teaching Methods Preferred by Grade 9 Students in Finland." *International Journal of Science and Mathematics Education* 8 (4): 611–632. doi:10.1007/ s10763-009-9177-8.
Krapp, A., and M. Prenzel. 2011. "Research on Interest in Science: Theories, Methods, and Findings." *International Journal of Science Education* 33 (1): 27–50. doi:10.1080/09500693.2010.518645.
Lavonen, J., J. Gedrovics, R. Byman, V. Meisalo, K. Juuti, and A. Uitto. 2008. "Students' Motivational Orientations and Career Choice in Science and Technology: A Comparative Investigation in Finland and Latvia." *Journal of Baltic Science Education* 7 (2): 86–102.
Levitt, K. E. 2001. "An Analysis of Elementary Teachers' Beliefs regarding the Teaching and Learning of Science." *Science Education* 86 (1): 1–22. doi:10.1002/()1098-237X.
Newton, D. P. 1988. "Relevance and Science Education." *Educational Philosophy and Theory* 20 (2): 7–12. doi:10.1111/j.1469-5812.1988.tb00139.x.
Osborne, J., S. Simon, and S. Collins. 2003. "Attitudes Towards Science: A Review of the Literature and Its Implications." *International Journal of Science Education* 25 (9): 1049–1079. doi:10.1080/0950069032000032199.
Roberts, D. A. 2007. "Scientific Literacy/science Literacy." In *Handbook of Research on Science Education*, edited by S. K. Abell and N. G. Lederman, 729–780. Mahwah, NJ: Lawrence Erlbaum Associates.
Roberts, D. A., and R. W. Bybee. 2014. "Scientific Literacy, Science Literacy, and Science Education." In *Handbook of Research on Science Education*, edited by N. G. Lederman and S. K. Abell, 545–558. Vol. II. New York, NY: Routledge.
Schreiner, C., and S. Sjøberg. 2004. Sowing the seeds of ROSE. *Background, rationale, questionnaire development and data collection for ROSE (The Relevance of Science Education)—A comparative study of students' views of science and science education*. Acta Didactica, 4: 1–120.
Simon, S., and R. Amos. 2011. "Decision Making and Use of Evidence in a Socio-scientific Problem on Air Quality." In *Socio-scientific Issues in the Classroom. Contemporary Trends and Issues in Science Education*, edited by T. D. Sadler, 167–192. Dordrecht: Springer.
Sjøberg, S., and C. Schreiner. 2010. *The ROSE Project: An Overview and Key Findings*, 1–31. Oslo: University of Oslo.
Stuckey, M., A. Hofstein, R. Mamlok-Naaman, and I. Eilks. 2013. "The Meaning of 'Relevance' in Science Education and Its Implications for the Science Curriculum." *Studies in Science Education* 49 (1): 1–34. doi:10.1080/ 03057267.2013.802463.
Treagust, D. F., and C.-Y. Tsui. 2014. "General Instructional Methods and Strategies." *Handbook of Research on Science Education* 2: 303–320.
Tytler, R. 2007. *Re-imagining science education: Engaging students in science for Australia's future*. Camberwell, VIC: Australian Council for Educational Research.
Uitto, A., & Kärnä, P. 2014. "Teaching methods enhancing grade nine students' performance and attitudes towards biology." In Research For Evidence-based Teaching and Coherence in Learning, edited by N. Constantinou, A. Papadouris and A. Hadjigeorgiou, 315-321. Nicosia, Cyprus: ESERA.
Uitto, A., P. Kärnä, and R. Hakonen. 2013. "Relationship between the Working Methods and Lower Secondary School Students' Performance and Attitudes Towards Biology [In Finnish]." *LUMAT* 1 (3): 263–278.