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Food in science, science in food – Interdisciplinarity in science/chemistry and home economics lower secondary curricula across three countries

Erik C. Fooladi [a], Maiju Tuomisto [b] and Janni Haapaniemi [c]

[a]Department of Science and Mathematics, Volda University College, Volda, Norway; [b]Malmi Comprehensive School, Helsinki, Finland; [c]Department of Education, Faculty of Educational Sciences, University of Helsinki, Helsinki, Finland

ABSTRACT

Food, cooking, and eating are commonly used as contexts or legitimations to teach and communicate science. However, for teaching to have contextual credibility, the relationship between subject and context is a relevant area of study. The present contribution describes an analysis of curricula from three Nordic countries shedding light on conditions for interdisciplinarity and/or curricular integration between the subjects science/chemistry on the one side, and home economics on the other. A two-phase documentary analysis was conducted on curricula from Finland, Norway, and Sweden from 2006 to 2020, revealing substantial potential for interdisciplinary collaboration and/or curricular integration. This is seen both in common declarative knowledge content ('*declarative knowledge overlap*') and, more interestingly, meeting points between subject-dependent practices and ways of thinking ('*transfer of practices and ways of thinking*'). The second inductive phase produced 11 themes common to the subjects. Possibilities and challenges are discussed in relation to the subjects' epistemologies and ontologies, as well as practitioners' competencies, attitudes, and creativity for subject boundary-crossing. Consequently, we conceptualise teachers' roles as lying in the span between 'teacher as polymath' and 'teacher as collaborator'. The present work also provides a instrument for exploring curricular conditions for interdisciplinarity between subjects on a more general basis.

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Introduction

School subjects in primary and secondary education, the sciences being no exception, do not exist in a vacuum but are parts of a larger picture, related to other subjects, as well as topics and issues transcending subject boundaries. Furthermore, there is no lack of

CONTACT Erik C. Fooladi erik.cyrus.fooladi@hivolda.no Department of Science and Mathematics, Volda University College, P.O. Box 500, 6101 Volda, Norway

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examples, initiatives, policy statements and research arguing for various forms of inter/multi-/transdisciplinary approaches or curricular integration of various sorts. Examples from the literature include context-based education (Gilbert et al., 2011; King & Ritchie, 2012), curriculum integration (Venville et al., 2012), STEAM (Colucci-Gray et al., 2017; Herranen et al., 2021), and socio-scientific issues (Karisan & Zeidler, 2017). Herein we present findings from a mixed methods documentary analysis of national curricula in science/chemistry and home economics across three Nordic countries to shed light on possibilities and challenges for such approaches afforded by the curricula.

Inter-transdisciplinarity and curriculum integration

With collaboration or integration between two or more subjects come possibilities and challenges, such as power relations, the roles played by the subjects in the collaboration, which knowledge and competencies are promoted, who benefits, and whether it is the subject or the phenomenon/issue that should dictate the goals for teaching. From the perspective of context-based education, Herranen et al. (2019) highlight the need to take the context seriously if contextualisation is to be credible and not merely a post-hoc justification for the instruction of content. From the perspective of curriculum integration, Pountney and McPhail (2017) contributed to the distinction between 'weaker' and 'stronger' integration. Weaker integration is conceptualised as functional/pragmatic and discipline-oriented, where outcomes are oriented towards disciplinary knowledge and conceptual orientation is internal to the subject. In stronger integration, conceptual orientation is external to the subject, the integration may be contextual/principled, and learning outcomes are often found outside common subject content knowledge. Here, the outcomes may, e.g. be of a more general nature (meta-skills, broader insights) and aimed outwards from the subject and towards an issue, topic, or context. This resembles much what Gilbert (2006) from the perspective of context-based approaches termed 'context as social circumstance'.

Science in food – food in science

The work described herein is contextualised in issues often used to justify or promote science learning and interest, namely, how we as humans relate to food, cooking and eating. Framing the kitchen as an arena, and cooking as a context, for learning and promotion of knowledge transfer between school and life outside organised education was promoted already a century ago by John Dewey (1938, p. 79; Heldke, 1992). However, when relating science to life outside school complex notions of contextualisation of science education are required, as, for instance, described in work on context-based approaches (Gilbert, 2006; Herranen et al., 2019; King, 2012; Muñoz-Campos et al., 2020) and humanistic and community-based perspectives on science education (Aikenhead, 2006; Calabrese Barton & Tan, 2009; Roth & Lee, 2004). Simply knowing that food is composed of molecules and that cooking is a chemical reaction will not necessarily help in the kitchen or provide culinary benefit. In short, if food is used as justification, the science taught should have contextual credibility and that learning should have functionality and/or relevance (Herranen et al., 2019). This has consequences for the teacher because such context-bound (science) knowledge is seldom covered in science curricula, nor as part of most science teachers' education. This is what Gilbert (2006) termed 'extra-situational knowledge', i.e. context-specific knowledge required to guide students in inquiry and learning within a specific context and ties in with Pountney and McPhail's (2017) notion of stronger integration.

Science, food, and home economics

In many countries, food and cooking are included in curricula as part of the subject home economics (IFHE, 2008) or its counterparts such as Family and consumer sciences in US curricula (Poirier et al., 2017). An initial search for 'home economics' and related terms revealed that research studies involving science and home economics are scarce to non-existent in science education journals (Tuomisto, 2021). Teachers wanting to use food, cooking, or eating as context are thus left with two possibilities. They could, in addition to deep knowledge in science, acquire knowledge and skills in the domains related to food, personally taking responsibility for contextualising science: 'Teacher as polymath'. Alternatively, they could reach out to colleagues for collaboration: 'Teacher as collaborator'.[1] Science and home economics have as school subjects overlapping content, stemming from shared knowledge bases on topics such as nutrition, agriculture, production, consumption and sustainability, properties and functionality of materials and detergents, critical thinking, etc. (e.g. Poirier et al., 2017; Tuomisto et al., 2017). This relationship and overlap between science and home economics indicate obvious possibilities for cross-pollination/fertilisation. Such collaboration has, e.g. been shown to be productive for teaching mathematics and home economics (Brante & Brunosson, 2014).

Our impression as professionals in science and home economics education and research is that home economics practitioners are aware of science as a related or 'neighbour' subject, but that it is less so the other way around. The present contribution thus aims to explore the potentials for collaboration between these subjects. A central question is what the conditions could be for engaging in integration or inter-transdisciplinary teaching. Which possibilities are provided, or allowed, by the respective curricula? Which challenges and frictions may arise? How do the two subjects relate to shared socio-scientific issues? Do the subjects have similar, or rather different, perspectives on food, either conceptualised as chemical substances and biological matter, culture, or otherwise? To which degree are the practices and ways of thinking in the two subjects similar or different?

Scope, delimitation, and research questions

We have sought to approach the questions above by way of a mixed-methods content analysis of science and home economics curricula for lower secondary schools in three Nordic countries: Finland, Norway, and Sweden. We focus on topics relating to food, cooking, and eating, and less on the subsequent events in the body, i.e. health and nutrition. Put simply, our focus is how the curricular texts from the two subjects relate to content, teaching and learning about food from it is harvested until it is swallowed, and the dishes are done. This is not to indicate that health and nutrition are not relevant or interesting. However, in the Western tradition/culture (here disregarding alternative medicine) the epistemic authority in nutrition lies in science/scientific knowledge and is thus described in both science and home economics curricula from a scientific perspective. Still, whilst science education to a strong extent builds on systematically derived scientific knowledge, often based in Western epistemic culture,[2] home economics has an eclectic epistemic base including both scientific, crafts-based, and aesthetic knowledge traditions (IFHE, 2008; Turkki, 2015). Thereby food, cooking and eating are arenas for the encounter between science-based and crafts-/experience-based knowledge, and thus an exploration of science learning applied 'in the world' as well as epistemic border-crossings (Calabrese Barton & Tan, 2009; Lee et al., 2020). When science and food meet as 'kitchen chemistry' experiments and activities, questions of epistemic nature are seldom discussed. Approaches taking this into account could evoke interesting and important aspects with regard to epistemology across subject boundaries.

In Finland and Sweden chemistry exists as a separate subject from lower secondary education, whereas in Norway chemistry is part of an integrated science curriculum throughout primary and secondary school. Our study, therefore, includes chemistry curricula from Finland and Sweden and science curricula from Norway. We wanted to study curricular content experienced by all students, and since home economics is compulsory only in lower secondary education across the three countries, we have limited our analyses to this level (students 13–16 years of age). For the same reason we have excluded curricula for elective, non-compulsory, subjects. Our study is thus guided by the following research question:

> When food, cooking and eating are used as contexts, which possibilities, and challenges for inter/transdisciplinarity and integration are found in three Nordic curricula for lower secondary science/chemistry and home economics education?

In the following, we will use the abbreviations 'S/C' for science/chemistry and 'HE' for home economics, 'SSI' denotes socio-scientific issues, and 'ITI' is used to denote inter-transdisciplinarity and integration.[3]

Methods and materials

The curricula subject to analysis were the Finnish curriculum of 2014 (The Finnish National Board of Education, 2014), the Norwegian curriculum of 2006, revised in 2013 (The Norwegian Ministry of Education and Research, 2006/2013), the Norwegian curriculum of 2020 (The Norwegian Ministry of Education and Research, 2020) and the Swedish curricula of 2011 and 2019 (Swedish National Agency for Education, 2011/2019). The texts were analysed by means of documentary research methods (Cohen et al., 2007) following a two-phase Quan-qual(-quan) sequence (Johnson & Onwuegbuzie, 2004) to deductively produce quantitative code counts, qualitatively generating themes, and finally quantifying and cross-referencing the theme codes with the initial codings.

The countries' curricula are structured differently, so the texts were initially studied for which parts to include in the analysis. To ensure the analysed material was of comparable nature across countries, and to prevent counting the same codes twice due to recurring descriptions of some content, the parts describing objectives, aims and core content were selected for analysis (Table 1). General subject descriptions, cross-cutting concepts and assessments were therefore omitted.

Table 1. Curriculum texts included in analysis (Swe2019 ≈ Swe2011, therefore, not analysed separately).

Country	Year	Abbreviation	Subject	Parts included in analysis	Total word count of analysed text
Finland	2014	Fin2014	Chemistry	Objectives of instruction Key content areas	802
			Home economics		417
Norway	2006/13	Nor2006/13	Science	Competence aims	603
			Food and health		218
	2020	Nor2020	Science		350
			Food and health		170
Sweden	2011	Swe2011	Chemistry	Core content	335
			Home and consumer science		276
	2019	Swe2019	Chemistry		358
			Home and consumer science		257

For Nor2006/13 and Swe2011/2019, both original and the official English versions were analysed, where one researcher coded the original and another coded the English version. The Finnish curriculum was analysed by two researchers in the original language version. After independent coding, the codings were negotiated to a consensus, arriving at a common justified result. Nor20 and Swe2019 were analysed by one researcher in their original languages based on experience and consensus negotiations for the first three curricula. As Swe2019 for the sections included in our study was seen to differ insignificantly from Swe2011, we have for our purpose considered Swe2011 and Swe2019 as identical.

Data analysis

Phase 1 – deductive quantitative analysis to identify possibilities for ITI

A quantitative deductive step was undertaken to search for possibilities for ITI between the two subjects. Using ATLAS.ti 7 and 8 software (Archiv für Technik, Lebenswelt und Alltagssprache), the S/C texts were coded for instances of what we considered to represent 'clearly food', 'potentially food' and 'nature of home economics and multiliteracy'. Likewise, HE curricula were coded for instances of 'clearly chemistry', 'clearly natural sciences', 'potentially chemistry', 'potentially natural sciences', and 'nature of science and multiliteracy'.[4] The codes 'nature of < subject > and multiliteracy' are conceptualised as the process and thinking aspects of a subject as described in further detail below. The frequencies of the respective codes were counted, and the relative percentage frequencies were calculated, giving what we have termed 'ITI codes' as shown in Figure 1. The codes are not necessarily mutually excluding, and the same text fragment could be coded with more than one code, for instance for text that could be seen to include both chemistry and biology, or both chemical declarative knowledge and procedural knowledge and skills. For this reason, we have not included cumulative code counts as this would result in double counting parts of the texts.

Phase 2 – qualitative analysis and inductive generation of themes

The coded sections were subsequently analysed by individual researchers to inductively create topical themes following a constant comparison approach and coded in Atlas.ti. The researchers compared themes and negotiated to produce theme codes across the

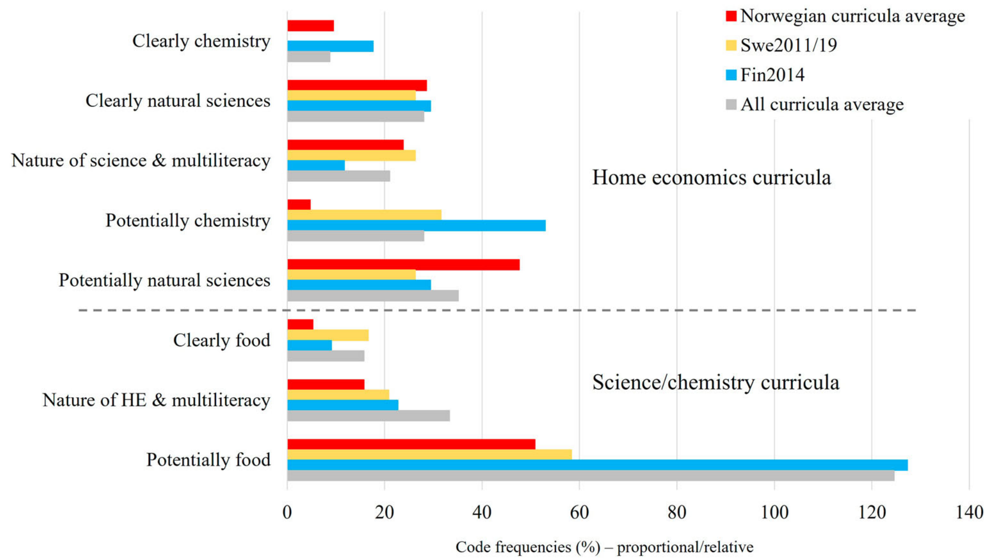

Figure 1. Proportionally, how much of curricular goals in science/chemistry can potentially be taught related to food, and likewise which proportion of goals in home economics can be taught related to science/chemistry? (Colours corresponding to country as given in legend. Average calculated as the number of curricular goals with at least one coding divided by total number of goals in respective text).

subjects (Figure 4, see Appendix for code descriptions). This inductive phase was informed by the researchers' prior familiarity with the subjects, curricula, teaching, and educational research in the two subject domains. Theme codes are not mutually excluding, and the same text fragment could be coded with more than one theme since many issues are complex and relate to multiple aspects and content within a subject. For instance, food-related climate change would be coded both as sustainability and as a socio-scientific issue. Contingency tables of themes and ITI codes shown in Figures 5 and 6 provide visual representations to reveal patterns within or between the subject curricula.

Validity and reliability

Validity is ensured through clear and detailed method descriptions combined with parallel coding by two researchers, followed by negotiation, to provide internal rigour and transparency. Nor2020 was coded by a single researcher subsequently to coding and analysis of the first three, following the same pattern as previous codings by pairs of researchers. The researchers are native speakers of two out of three languages, and mastery of the third is considered sufficient to ensure a good understanding of all texts in their original language. All three coders are professionals in HE education, whereas two are also professionals in chemistry and science education. This insider perspective for both subjects is particularly important to secure ecological and cultural validity when analysing the texts (Cohen et al., 2007).

The stepwise coding towards increasingly higher detail and specificity further contributes to reliability and ecological validity, as every instance of ITI coding ('clearly chemistry',

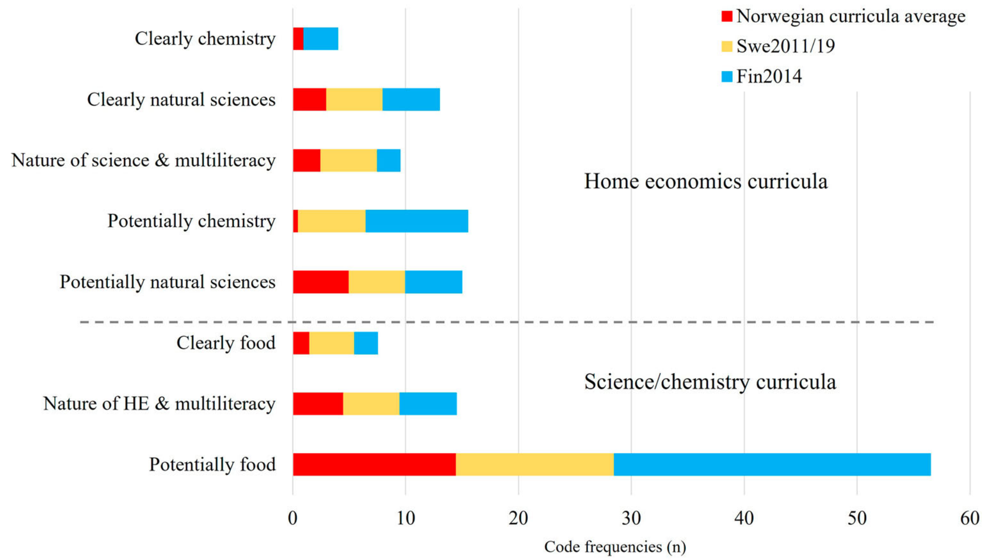

Figure 2. The number of instances marked with the various ITI codes across the curricula. Average is the number given for the two Norwegian curricula (no. goals coded/no. goals total). Bar colours correspond to the country as shown in legend, grey bar is the average value across curricula (average calculated as the number of curricular goals with at least one coding divided by total number of goals).

'clearly food', etc.) is validated by one or more theme codes, thereby explicitly justifying each coding instance with a theme. Furthermore, every instance of theme coding is validated by obligating the coders to be able to point to real-world teaching cases or descriptive accounts of how each coding instance could be taught in practice. For each instance of coding, we ask

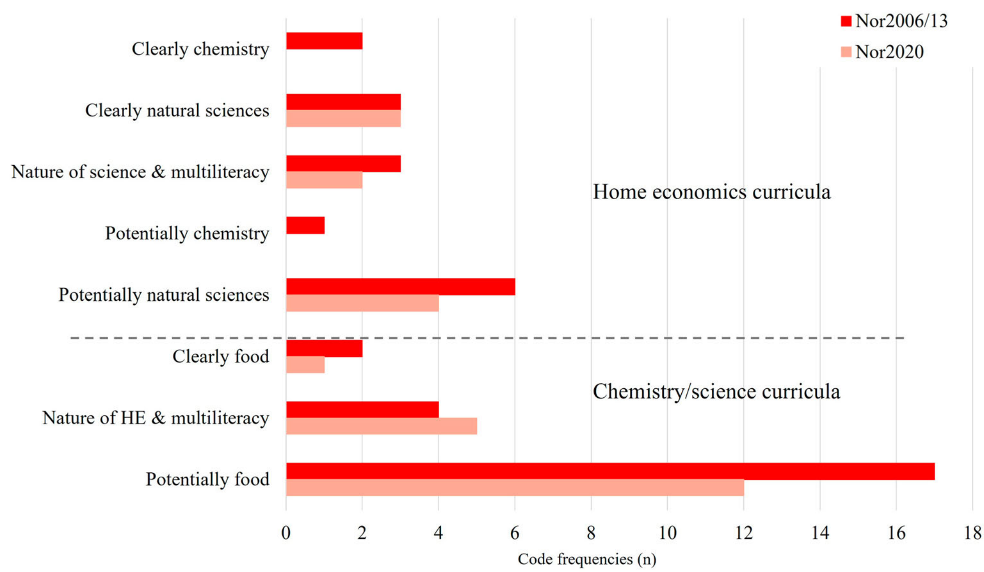

Figure 3. The number of aims coded with the various ITI codes in two consecutive Norwegian curricula. Red bar denotes Nor2006/13, pink bar denotes Nor2020.

Table 2. Selected quotes from the curricula for 'clearly < … >' and 'nature of < subject > and multiliteracy'. See Appendix for more examples of coding instances.

Clearly food (in S/C)	The pupils familiarise themselves with carbon and its compounds as well as nutrients (Fin2014) [p]rovide examples of how Sami people make use of resources in nature (Nor2006/13). [d]escribe the greenhouse effect and [give an] account [of] for factors that can bring about [cause] global climate change (Nor2020). Content [constituents?] of food and beverages and their importance for health (Swe2011/19).
Clearly chemistry (in HE)	The planning and implementation of meals and different meal occasions guide the pupils to consider their choices and habits related to food and eating from the viewpoints of nutritional recommendations, food safety, the food chain, food knowledge and skills, economical and ethical choices as well as reliable information related to food (Fin2014). [a]ssess the content of energy and nutrients in food and beverages and apply the findings when preparing food (Nor2006/13). [e]xplain which nutrients foods contain (Nor2006/13).
Clearly natural sciences (in HE)	[t]o guide and encourage the pupil to select and use materials, utensils, appliances, and information and communication technology in a way that promotes well-being and sustainable consumption (Fin2014). [*p*]rovide examples of how kitchen utensils, methods of preparation or eating habits have changed over time or moved geographically and explain how this has influenced people's lives (Nor2006/13). [c]ritically evaluate [assess] information on food production [manufacture] and discuss how consumer power can influence local and global food production [manufacture] (Nor2020). How food and other goods are produced and transported, and how they impact the environment and health (Swe2011/19).
Nature of HE and multiliteracy (in S/C)	[t]o encourage the pupil to formulate questions about studied phenomena and to further develop the questions to serve as a basis for research and other activities (Fin2014). [i]dentify natural science arguments, facts and assertions in texts and visual information from newspapers, brochures and other forms of media and evaluate the content of these in a critical manner (Nor2006/13). [g]ive examples of and discuss current dilemmas related to the exploitation [use] of natural resources and loss of biodiversity (Nor2020). Critical examination of information and arguments which pupils meet in different sources and societal discussions related to chemistry (Swe2011/19).
Nature of science and multiliteracy (in HE)	[t]o guide the pupil to practice listening, constructive discussion, and argumentation in the planning and implementation of learning assignments (Fin2014). [u]se digital tools to assess the content of energy and nutrients in food and beverages and apply the findings when preparing food (Nor2006/13). [a]ccount for and critically evaluate [assess] claims, recommendations and information about diet and health (Nor2020). Different methods of baking and cooking. How choice of method influences the work process and results (Swe2011/19).

ourselves whether we are familiar with existing cases of teaching, can describe how we would teach this in practice, or can point at published cases, to justify this instance of coding. Thus, reliability is supported by a stepwise process from a general level towards increasing detail, ending up in examples from the classroom, lab, or kitchen.

Results

First, we present quantitative data for inter-transdisciplinarity and integration (ITI codes), followed by results for theme codes, with selected text excerpts. A longer list of excerpts from each curriculum text is given in the Appendix.

Inter-transdisciplinarity and integration (ITI) codes

If we, hypothetically, wanted to teach science/chemistry using food to the maximum possible extent, how large proportion of S/C could that entail? And, how much of HE can be said to be related to S/C? This is illustrated in Figure 1, showing the proportion of curricular goals in S/C and HE coded with instances of the other subject domain. On average across all the curricula studied, ca. 16% of S/C goals have been coded with 'clearly food' (grey bar, 'clearly food'), and 9% and 28%, respectively, of the HE curricula are coded with at least one instance of 'clearly chemistry' or 'clearly natural sciences' (grey bars, 'clearly chemistry' and 'clearly natural sciences'). With respect to the 'potentially food' code for S/C curricula, the proportions are substantially higher, and in all curricula at least 50%. This means that we find the possibility of teaching at least 50% of science or chemistry curricula in some way or another related to food or kitchen, should we hypothetically desire to do so. This does not indicate that one *should* do so in all possible cases but indicates a substantial *potential* for collaboration and cross-fertilisation. Also, it indicates that one might meet such possibilities several, or many, times throughout the lower secondary years. For Fin2014 the value for 'potentially food' exceeds 100%, which is a result of 'central content' paragraphs (counted as single text elements) containing several sentences covering different content that is coded individually. The three coding instances in the following excerpt, counting as one paragraph in our analysis, exemplify this:

> **C6 Properties and changes in substances:** [The pupils familiarise themselves with the changes of energy and substances in chemical reactions.] [They make observations on reactions rate and consider factors that influence it.] [They get acquainted with the carbon cycle and its significance for life.] [<u>They familiarise themselves with concentration and acidity in connection to everyday examples</u>]. [They practice interpreting the language of chemical symbols and simple reaction equations] (excerpts from Fin2014. examples of text coded as 'potentially food'. Underlined text was coded as 'clearly food').

For text coded 'clearly < … >' (food, chemistry, natural sciences), the curricula could be said to imply a more explicit indication that one preferably *should*, rather than *could*, draw on content and perspectives across subjects or contexts. This could, for instance, be if the S/C text explicitly mentions food, or if it is considered inevitable to include food in teaching the given goal (see Table 2 for selected quotes). Content coded with 'nature of < subject > and multiliteracy' includes goals such as argumentation, critical thinking, source awareness/evaluation, knowledge production, (multimodal) documentation and communication, formulating questions and generating hypotheses, dilemmas and wicked problems, decision-making, first-/second-hand inquiry and experimental skills, subject-specific numeracy etc. (Halinen et al., 2015).

While Figure 1 points towards possibilities at a proportional level, we wanted to explore how many *instances* of such possibilities may be present for educators throughout the lower secondary years. Figure 2 gives an overview, indicating, for instance, that a Norwegian science teacher during lower secondary may have (at least) 15 possibilities to use food to teach science content (red portion of 'potentially food' bar), whereas chemistry teachers in Sweden and Finland would have up to 14 and 28 such possibilities, respectively (yellow and blue portions of 'potentially food' bar). Instances where HE content is coded as 'clearly chemistry' or 'clearly natural sciences', and conversely S/C curricula coded as ‘clearly food’ indicate several instances of explicit connections across all three countries (Figure 2). In summary, curricula from all three countries give roughly similar patterns, with substantial possibilities for ITI approaches from both sides.

Temporal stability

As we have included two consecutive curricula from Norway, we may explore whether the findings are products of their time or if they are temporally generalisable. In Figure 3, we compare the two Norwegian curricula published over a time span of 14 years. Except for ‘clearly chemistry’ and ‘potentially chemistry’ in HE, and ‘potentially food’ in science, the two curricula follow the same pattern. Although the number of coding instances is similar, proportionally the frequency is higher in Nor2020. The latter text has comparably fewer aims in total (Table 1) as a result of the 2020 reform aiming at reducing curricular overload and promoting deep learning (EURYDICE, 2019). In summary, we believe that our findings indicate a certain temporal stability for the Norwegian curricula.

Theme codes

The subsequent analysis of the coded instances gave rise to 10 themes and theme counts, as shown in Figure 4. For a few cases, we did not find the ITI coding to fit within the theme codes, and these thus gave rise to the eleventh theme called ‘uncoded’ (see Appendix for theme descriptions).

Tuomisto et al. (2017) have previously shown that the Norwegian HE curriculum from 2006/13 focusses substantially stronger on food, meals and cooking compared with Fin2014 and Swe2011, and topics such as household and economy found in the Finnish and Swedish HE curricula are virtually non-existent in Nor2006/13. This is carried over to Nor2020 and is seen by the absence of explicit instances of Th9 (Hygiene and safety) and Th10 (Detergents) in Nor2006/13 and Nor2020 (hygiene is nevertheless present in the Norwegian HE curricula but covered in lower grades, presumably implicitly expected to be established as practices to be carried over to later grades).

Cross-linking ITI codes with theme codes

We were interested in how the themes relate to the various ITI coding instances. Figures 5 and 6 show contingency tables illustrating relationships between ITI codes and theme codes *within* the parts of the material coded as clear or potential instances of ITI. This may provide answers to ‘who invites who’. For instance, we see that there are particularly many opportunities for ITI approaches from the side of S/C in themes Th1 (Experiment, procedure, and inquiry), Th4 (Argumentation and SSI), Th6 (Sustainability) and Th8 (Food as chemistry). From the side of HE, this is mutual particularly for the first three, thus indicating a common presence in curricula of the same themes. Note that in some cases, such mutuality may be in the declarative content of the subjects, whereas in other cases the procedural and thinking aspects need to be considered to identify the possibilities. For other themes, for instance, Th7 in Fin2014, historical development and technology, the counts are low in S/C curricula, whereas numbers are higher in HE curricula. Here, the HE teacher may be interested in inviting S/C to contribute,

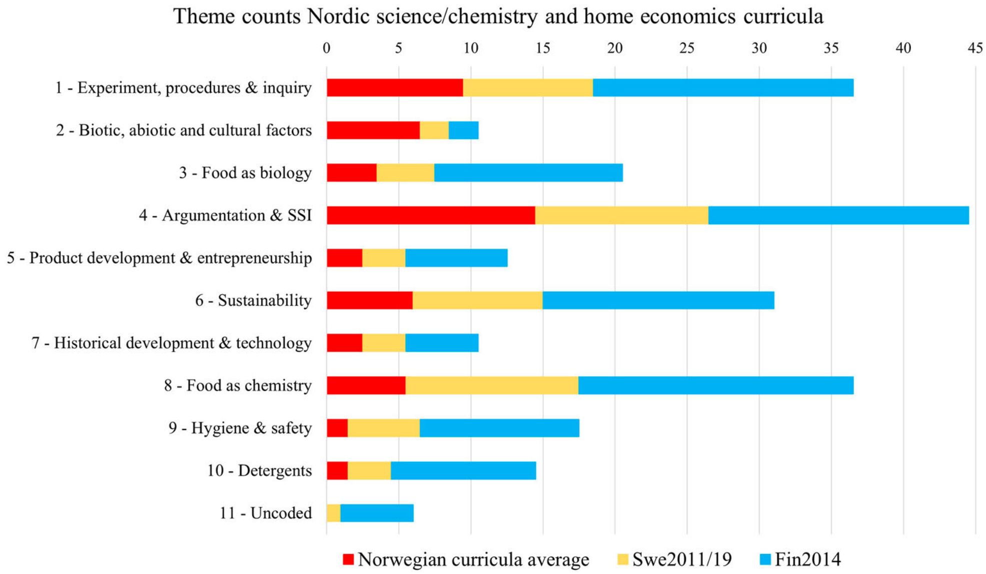

Figure 4. Number counts of theme codes in the four curricula. Red denotes Norwegian curricula (average count of the two), yellow denotes Swe2011/19, blue denotes Fin2014.

whereas the S/C teacher does not find explicit motivation in the curriculum for such an initiative.[5]

'Nature of < subject > and multiliteracy' versus declarative knowledge

From a science/chemistry perspective, the theme codes cover broad parts of S/C curricular content types, including declarative knowledge, practical skills, inquiry, argumentation,

	Theme 1 Experiment, procedures & inquiry	Theme 2 Biotic, abiotic and cultural factors	Theme 3 Food as biology	Theme 4 Argumentation & SSI	Theme 5 Product development & entrepreneurship	Theme 6 Sustainability	Theme 7 Historical development & technology	Theme 8 Food as chemistry	Theme 9 Hygiene & safety	Theme 10 Detergents	Theme 11 Uncoded
Swe2011/19 chemistry											
Clearly food	0	1	1	2	0	3	0	2	1	1	0
Potentially food	5	1	1	6	1	4	1	8	1	0	0
Nature of HE & multiliteracy	4	0	0	4	0	1	0	1	1	1	0
Sum	9	2	2	12	1	8	1	11	3	2	0
Fin2014 chemistry											
Clearly food	0	0	2	0	0	0	0	2	0	1	0
Potentially food	11	0	7	7	4	8	0	13	5	6	3
Nature of HE & multiliteracy	3	0	1	3	1	1	0	1	1	1	2
Sum	14	0	10	10	5	9	0	16	6	8	5
Nor Science 2020											
Clearly food	0	0	0	1	0	1	0	1	0	0	0
Potentially food	4	0	0	5	3	6	1	4	3	3	1
Nature of HE & multiliteracy	2	0	0	3	0	5	0	3	1	0	0
Sum	6	0	0	9	3	12	1	8	4	3	1
Nor Science 2006/13											
Clearly food	0	0	0	1	0	2	0	1	0	0	1
Potentially food	9	3	0	4	2	9	0	2	0	6	2
Nature of HE & multiliteracy	3	0	0	0	0	5	0	0	0	0	1
Sum	12	3	0	5	2	16	0	3	0	6	4

Figure 5. Contingency table of the number of instances of ITI codes and theme codes in science/chemistry curricula. The intensity of colour correlates with the number of instances coded for ease of reading. The numbers are counts *within* the parts of curricula already coded clear or potential instances of ITI.

	Theme 1 Experiment, procedures & inquiry	Theme 2 Biotic, abiotic and cultural factors	Theme 3 Food as biology	Theme 4 Argumentation & SSI	Theme 5 Product development & entrepreneurship	Theme 6 Sustainability	Theme 7 Historical development & technology	Theme 8 Food as chemistry	Theme 9 Hygiene & safety	Theme 10 Detergents	Theme 11 Uncoded
Swe2011/19 HE											
Clearly chemistry	0	0	0	0	0	0	0	0	0	0	0
Clearly natural sciences	1	0	1	1	0	2	2	0	3	2	0
Potentially chemistry	3	0	2	1	1	0	0	2	2	2	0
Potentially natural sciences	3	0	1	1	1	0	0	2	0	0	1
Nature of science & multiliteracy	2	0	1	3	1	1	0	1	0	0	0
Sum	9	0	5	6	3	3	2	5	5	4	1
Fin2014 HE											
Clearly chemistry	2	1	2	2	1	3	2	2	3	1	0
Clearly natural sciences	1	0	0	3	0	3	1	0	0	0	0
Potentially chemistry	4	1	1	5	1	4	3	1	3	1	0
Potentially natural sciences	3	1	1	4	1	1	2	1	2	1	0
Nature of science & multiliteracy	0	0	0	2	0	0	0	0	0	0	0
Sum	10	3	4	16	3	11	8	4	8	3	0
Nor 2020 HE											
Clearly chemistry	0	0	0	0	0	0	0	0	0	0	0
Clearly natural sciences	0	1	0	3	0	2	0	0	0	0	0
Potentially chemistry	0	0	0	0	0	0	0	0	0	0	0
Potentially natural sciences	3	1	2	3	1	1	1	0	0	0	0
Nature of science & multiliteracy	0	0	0	2	0	0	0	0	0	0	0
Sum	3	2	2	8	1	3	1	0	0	0	0
Nor2006/13 HE											
Clearly chemistry	1	0	0	1	0	0	0	2	0	0	0
Clearly natural sciences	0	0	0	2	1	1	1	0	0	0	0
Potentially chemistry	1	0	0	0	1	0	0	0	0	0	0
Potentially natural sciences	2	0	0	3	2	1	0	0	0	0	0
Nature of science & multiliteracy	1	0	0	3	0	0	0	1	0	0	0
Sum	5	0	0	9	4	2	1	3	0	0	0

Figure 6. Contingency table of the number of instances of ITI codes and theme codes in home economics curricula. The intensity of colour correlates with the number of instances coded for ease of reading. The numbers are counts *within* the parts of curricula already coded clear or potential instances of ITI.

socio-scientific issues (SSIs), technology, historical aspects, sustainability and more. These represent contextualisations of declarative knowledge, practices and thinking. Interestingly, some of the themes most frequently coded are related to procedural knowledge, practices and thinking (Th1, Th4, Th6). This is notable because we are of the impression that educators seeking or identifying opportunities for ITI or contextualisation, often look for possibilities in the declarative knowledge of the subjects, or the factual knowledge relevant to a given context. This corresponds with Wei and Long's (2021) analysis of lesson plans for context-based chemistry teaching, where concept focus clearly dominated over procedural and epistemic motivations for context-based teaching. Moreover, we find that the 'Nature of < subject > and multiliteracy' ITI codes correlate with theme codes Th1 (Experiment, procedures, and inquiry) and Th4 (Argumentation and SSI), which are those explicitly concerned with practices and ways of thinking of the subjects.

Discussion

From our analysis, the most striking observation is that all curricula offer many opportunities for ITI between these subjects, even when the obvious common topic of health/nutrition is kept aside. A fine-grained quantitative comparison between the countries is difficult due to the differing structure of the texts but it is possible to tentatively say that the count of S/C in HE for the Norwegian and Swedish curricula are roughly in the same range while the Finnish offers more possibilities. Considering that the curricula explicitly ask for the promotion of interdisciplinarity and knowledge transfer across subject and context boundaries, the ground is fertile, to put it mildly. However, we contend that even in cases where policy should *not* ask for ITI, curricular goals and subject content may still ask for such, as evidenced by the thematic coding.

Declarative knowledge versus domain/context-dependent practices and thinking

If we as educators strive towards innovative, context-based science teaching with relevance for all students and not only those aiming for STEM careers (Aikenhead, 2006), the instances of 'potentially food' may be just as relevant as 'clearly food'. We find that 'clearly food' instances are largely fact-oriented, circling around the subjects' declarative knowledge, representing a *declarative knowledge overlap*. However, many aims in science curricula such as inquiry, process- and thinking skills, argumentation, SSIs, etc. are found within the 'potentially food' category. Even though not all topics in HE are of scientific nature, scientifically inspired methods and thinking may still be applied in exploration and discussion. Such applications of scientific thinking and practices outside science, provide opportunities for *transfer across* subject boundaries (Illeris, 2009). If we as a science (education) community want to argue for the relevance of scientific practices and thinking in life outside formal education and the sciences, maintaining a transfer perspective, and an overlap perspective, is vital.

In science education socio-scientific issues are contexts where coordination of declarative knowledge with scientific practices and thinking is required (e.g. Sadler, 2009). Our results shown in Figures 5 and 6 indicate that SSIs and sustainability are areas with substantial common interest across the subjects. Typically, many SSIs are such that learners do not see the effects of their decisions or discussions within the foreseeable future on topics that reach far beyond what can be controlled or tested in class. Consequently, such inquiries are often based on second-hand inquiries with an appeal to authority strategies and trust in expert knowledge as evidence (Fooladi, 2020a). In contrast, many food-related SSIs are such that choices are made here and now with immediate effect, simply because food is cooked, evaluated, and eaten/experienced within a short time span. This is not a trivial matter, because the implication is that, when conceptualised as socio-scientific issues food, cooking and eating more easily provide for first-hand inquiries with a close relation and direct application of scientific knowledge, thinking and practices. Here, HE practitioners teaching in kitchens 'get their hands dirty' in a more literal sense in relation to learners' everyday lives than what is the rule in science teaching. As such, ITI approaches between the two subjects may help strengthen the experiential and material sides of teaching as called for by some in science education (e.g. Dahlin, 2001).

What becomes clear is that factual/declarative knowledge need not necessarily be the only, or major, criterion for ITI. For instance, although certain HE factual contents may not be explicitly scientific, we might still use scientifically inspired methods and thinking to explore and discuss them (Fooladi & Hopia, 2013; Hopia & Fooladi, 2019). Thus, rather than solely looking for *declarative knowledge overlap*, looking for possible *transfer of practices and thinking* across subject boundaries, or from subject to life outside school, may provide fruitfully.

Creativity, domain-specific knowledge, and nature of subjects

When dealing with food, we will soon meet questions calling for knowledge that is of extracurricular nature or at a level well above that of the learners' level, what Gilbert (2006) termed extra-situational knowledge. Indeed, until recently the natural sciences did not show much interest in what goes on in kitchens, be it in homes or restaurants, and much of that experienced and observed in the kitchen has not (yet) been studied by science (This, 2009). It is, therefore, not surprising if inquiry activities in the kitchen encounter content outside S/C curricula, some even not yet described by science altogether. The very same issues or questions may, on the other hand, have been described in the crafts-based knowledge culture of the kitchen existing alongside scientific knowledge in HE (e.g. Sutton, 2006). This provides fertile ground for authentic inquiry within or across subjects (Fooladi, 2021). Consequently, science teachers may need to seek knowledge beyond both curriculum and their own education when starting from ‘real-life issues’, be it as ‘polymaths’ handling the issue themselves or as ‘collaborators’ seeking support with colleagues. Successful ITI approaches thus require deep disciplinary knowledge, imagination, and creativity on the part of the teachers in identifying possibilities, knowing where to look, and guiding inquiry processes. At the same time, it requires that educators show interest in other subjects than their own, that they have a measure of broadness in perspective/outlook, and willing to take alternative positions/views (Venville et al., 2004; Venville et al., 2012), while at the same time not sacrificing subject-specific content or identities (Cassidy & Puttick, 2022). This may appear as a paradox because deep disciplinary knowledge would often be accompanied by a strong disciplinary identity, and occasionally, as shown by Naidoo (2010), greater resistance to curricular integration and epistemic reorientation. She indicates that epistemic and ontological compartmentalisation may be correlated with teachers’ educational level: The higher education, the greater the silo mentality. Although such correlations may be found, we do not believe, or accept, this to be a universal causality. Rather, it may be a result of attitude, first and foremost depending on the degree of pluralistic thinking and interest to maintain a broad perspective and openness to paradoxes, in line with Ramadier’s (2004) description of transdisciplinary thinking. As such, looking across curricular borders could provide an avenue to *teachers’* learning in the span between teacher as polymath and teacher as collaborator, if working with curricula is seen as an opportunity to learn and develop as professionals.

If we wish to stimulate trans-/interdisciplinary or integrated teaching, facilitation of meetings between different ‘natures of the subject’ with their respective epistemologies and ontologies is inevitable (Erduran et al., 2022; Fooladi, 2020b; Naidoo, 2010; Rennie et al., 2011; Venville et al., 2002). For instance, Pountney and McPhail (2017) have demonstrated how physical sciences on the one side, and social sciences, arts, and humanities on the other promote fundamentally different forms and structures of knowledge. According to McGregor (2011, p. 31), home economics draws its base of knowledge from various disciplines, such as natural sciences, social sciences, arts, and humanities. She contends that

> [t]hese root disciplines do not necessarily have familial needs in mind when they conduct their research or when they theorize. Consequently, home economics practitioners are challenged to extrapolate the information generated from these root disciplines, synthesize it, and convert it so it is applicable to the delivery of services to enable families and individuals to solve practical, perennial problems.

This points to a potential one-sidedness in the meeting between S/C and HE, where HE is bound to rely on S/C, whereas the opposite is not strictly required. On the other hand, food may provide legitimation of learning science content, and it may provide goals in science education per se. The plethora of PopSci material and communication linking science and food point to this. Hence, food may be either conceptualised as lying *within* the bounds of natural sciences and chemistry, or we may contend that science must stretch *outside* its own boundaries if it is to maintain contextual credibility when dealing with food, cooking, and eating. After all, framing food as pure chemistry, or one-sidedly seeking overlaps only in the declarative knowledge, may lead us along a path towards reductionism, with its concurrent problems of lack of relevance, transferability, and experienced credibility for the use of scientific knowledge altogether (Fooladi, 2020b). Furthermore, HE is a subject domain with a strong vein of inherent professionalism aiming towards context-based *actions* in particular contexts (McGregor, 2016). Science education, on the other hand, has traditionally been knowledge-oriented with ideals of abstraction and generalisation (although this has been challenged, see e.g. Dahlin, 2003). Thus, the two subjects to a certain extent represent differing world views, with paradoxes and conflicts as potential results. Such paradoxes are, however, not necessarily something to be shied away from or attempted to resolve towards consensus, but rather something to be made visible and articulated (Fooladi, 2020b; Ramadier, 2004). Since home economics draws on an eclectic range of subject domains, such tensions are even inherent *within* this subject. Although critical thinking, questioning, and evaluating claims, are promoted across curricula, such practices and attitudes may have different standing across subject domain cultures. In science, critical questioning is promoted as a virtue, holding up deduction and falsification as important principles. Conversely, for culinary practices embedded in a master-apprentice-oriented epistemic tradition, the authority has traditionally played an important role, and questioning the master has not been considered proper conduct (that said, recent decades have seen a movement in this respect, see e.g. Borkenhagen, 2017; Fooladi et al., 2019; Vega & Ubbink, 2008). The table is thus set for epistemic paradoxes and power relations to be played out when science is to 'play on away ground', moving into the kitchen to ask if science can make a difference in everyday cooking and eating practices. This way, teaching and collaborating across disciplinary boundaries may provide opportunities to challenge naïve notions, both among students and teachers, of science as solely a body of established facts to be learnt (Osborne, 2010), as well as uncovering the complex and multifaceted nature of everyday life issues. This also makes a case for Pountney and McPhail's (2017) stronger integration, as the issue at hand (context) and not the subject content, is made centrepiece.

We should mention that we are herein not discussing food science, industry and process technology as has been earlier discussed by, e.g. Dolfing et al. (2021) and Gilbert (2006) in relation to context-based teaching. These are contexts with quite different practices compared to food and cooking in homes or restaurants, and where the epistemic hegemony is firmly on the home ground of the STEM subjects. As such, contextualising science teaching in food industry is a rather different ballgame compared to that discussed herein.

Generalisability or transferability

The similarities across the three curricula indicate that our findings are not idiosyncratic for a single country, and the overarching results indicate validity across countries.

It could be said that the Nordic countries are similar in many respects, by some even 'seen as one' and that they have more in common than what separates them. However, our previous comparison of the HE curricula across the three countries indicate otherwise, as there are significant differences in some respects across the three countries despite geographic proximity and cultural similarities (Tuomisto et al., 2017). Moreover, we feel confident to say that science or chemistry curricula should not be very different across countries due to the inherent nature of science and chemistry as universal and generalisable across cultures, more so than, e.g. social sciences, history, religious studies, and indeed HE. Food is a phenomenon of universal nature, shared across the globe as something every human being must relate to, albeit with strong cultural influences. We would thus contend that there are good reasons to consider the results below being translatable to areas outside of the context of our study. For the same reasons, we believe our findings also bear relevance to, e.g. indigenous perspectives on science education. The fact that Norwegian curricula from Nor2006/13 and Nor2020 show similar trends provide some indication towards temporal generalisability.

Conclusions, implications, and outlook

Teaching productively across subject boundaries can be achieved either through close collaboration among educators ('teacher as collaborator'), or by the educator having insight into multiple disciplines and being open-minded to extra-situational knowledge ('teacher as polymath'). This becomes particularly clear when our results show that the greatest number of possibilities for ITI lie not in the notion of inter-subject overlap, but in the transfer of practices and ways of thinking between subjects. The ability to identify such possibilities requires creativity, interest, and willingness to move out of one's comfort zone on the part of educators. Thus, the notion of transfer, so often connected to the outcome on part of learners, becomes just as relevant for educators when they plan and carry out teaching. The challenge for home economics and science education practitioners in compulsory education is basically the same: Clearly linking school-derived knowledge to life outside formal education. Whether one seeks curricular integration or cross-subject collaboration, or one keeps matters within disciplinary boundaries, there are costs and benefits. Staying within subject boundaries may come with the cost of reduced relevance and transferability of that learnt, while crossing subject boundaries comes with costs of logistical challenges, assessment challenges, possible loss of disciplinary integrity, epistemic and cultural frictions. Nevertheless, educational policy might dictate towards ITI, as stated in recent Nordic curricula. Apart from policy, many issues and phenomena in life are inherently transdisciplinary and deserve to be treated as such, independently of other factors often used to legitimate integration (e.g. student motivation). Teaching solely within subject boundaries is expectedly easier but leaves to the learner to accomplish integration and transfer of knowledge across subject boundaries, which we contend is unproductive, even bluntly unfair. With this foundation, the question is probably not *if* we should seek ITI approaches where appropriate, but *how* to do it. Accomplishing this while not at the same time losing out on the declarative knowledge is surely more complex, messy, and difficult than staying safely within subject boundaries. The results herein indicate a substantial potential for a future where science/chemistry and home economics may find together in interesting and productive collaborations. This requires pluralism in action, epistemically and ontologically, with a willingness to take the perspective of 'the other', even accepting to live with unresolved paradoxes if two or more perspectives on an issue appear (or even are) irreconcilable (Fooladi, 2020b; Ramadier, 2004).

Finally, the present study represents a general methodology that may be of use when seeking to map out the potential for inter-transdisciplinarity and subject integration across subjects and geographical borders, as well as seeking relevance for science in vocational education on higher levels such as upper secondary and tertiary education.

Notes

1. Although we identify the two as binary, there is of course a gradual transition between them, or they could exist in parallel. It is also possible to envisage a gradual development between the two as result of work and collaboration in the intersection between subjects.
2. This is, by some, critiqued as one-sided and hegemonial, thus arguing for a science education more sensitive to indigenous and cross-cultural perspectives (e.g. Zidny et al., 2020).
3. We are aware that interdisciplinarity, transdisciplinarity and (curricular or subject) integration are distinct terms. However, for the purpose herein, where the focus is on the curricula and how they provide conditions for either of the three, we find the combination 'ITI' to be a sensible and functional construction. Furthermore, we have intentionally excluded multidisciplinarity on the grounds that this in our conceptualisation, in line with Ramadier (2004), does not require explicit interaction between subjects/domains.
4. We use 'science' to denote the school subject and 'natural sciences' to denote scientific disciplines forming the basis for school science. In the case of chemistry, the same word is used for both the school subject and the discipline, presuming the distinction (if relevant) will be clear from the context.
5. For science educators with a propensity towards promoting history of science in education, this may come as a disappointment. However, our example codings are limited to those where we find mutuality between S/C and HE, and there may be curricular goals in S/C that cover or allow for historical aspects other than those related to food.

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ORCID

Erik C. Fooladi http://orcid.org/0000-0001-7894-4747
Maiju Tuomisto http://orcid.org/0000-0002-2579-2572
Janni Haapaniemi http://orcid.org/0000-0003-3137-522X

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