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3 **Teachers' choice of content and consideration of controversial and sensitive**
4 **issues in teaching of secondary school genetics**

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12 **Disclosure statement**

13 Tuomas Aivelo has participated in writing biology textbooks for upper-secondary school
14 biology for eOppi Oy. None of the teachers involved in this study used biology textbooks
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18 **Abstract**

19 Science education strives to increase interest in science and facilitate active citizenship. Thus,
20 the aspects of personal and societal relevance are increasingly emphasised in science
21 curricula. Still, little is known about how teachers choose content for their teaching, although
22 their choices translate curricula to teaching practice. We explored how teachers choose
23 genetics content and contexts for biology courses on cells, heredity, and biotechnology by
24 interviewing ten Finnish upper-secondary school teachers. We specifically studied how the
25 teachers described teaching on genetically modified organisms, hereditary disorders, and
26 human traits as teachers have different amounts of freedom in choosing contents and contexts
27 in these themes. We analysed interviews with theory-guiding content analysis and found
28 consistent patterns in teachers' perceptions of the main themes in genetics teaching, teacher
29 inclinations towards teaching genetics in human context and perceptions of students' interest
30 in different topics. These patterns, which we call emphasis of content in genetics teaching
31 could be classified to *Developmental*, *Structural* and *Hereditary*. Teachers with
32 *Developmental* emphasis embraced teaching genetics in human context while teachers with
33 *Structural* emphasis avoided them. Contrary to previous research, the less experienced
34 teachers were most open to discussing human genetics. In general, teachers' justified their
35 choices by national, local school, and teacher's personal-level factors. While teachers
36 mentioned that societal and personal contexts are important, at the same time teachers never
37 framed main themes in genetics with these contexts. We conclude that more emphasis should
38 be put on how teachers handle issues with societal or personal relevance.

39 **Keywords:** *genetics content, curriculum, biology education, socio-scientific issues*

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41

Introduction

42 Curriculum articulates learning goals in school and thus guides teaching. In Finland, the
43 national curricular goals are managed by legislation, the municipal authorities have an
44 autonomy to provide and organize education at local level and teachers are valued as experts
45 who are able to develop and implement the school-specific curriculum (Niemi, Toom, &
46 Kallioniemi, 2012). Thus, the curriculum leaves a remarkable responsibility and freedom to
47 the teachers to implement education, for instance, in emphasizing the contents of upper
48 secondary school courses (Finnish National Board of Education, FNBE, 2003; Niemi et al.,
49 2012). While the curricular development and its effectiveness are studied extensively (e.g.,
50 Hargreaves, Lieberman, Fullan, & Hopkins, 2010; Niemi et al., 2012), there is less research
51 done on how teachers choose contents for their teaching.

52 Teacher beliefs guide to a substantial extent how teachers value different aspects of
53 knowledge and how much they emphasise different content (Cheung & Wong, 2010;
54 Cronin-Jones, 1991; Haney, Czerniak, & Lumpe, 1996). Teachers' 'personal knowledge' is
55 not static, but is formed through everyday experiences and formal schooling, including
56 teacher education, and continues to be molded in continuing professional education
57 (Gess-Newsome & Lederman, 1995; Henze, Van Driel, & Verloop, 2007; Van Driel,
58 Beijaard, & Verloop, 2001), and this personal knowledge shapes teaching to a large extent
59 (Hashweh, 1987, 2005; van Driel, Bulte, & Verloop, 2008). Nevertheless, personal
60 knowledge often manifests through rules-of-thumb, rather than formal design (Wieringa,
61 Janssen, & van Driel, 2011). Consequently, curricular change can cause very little change in
62 teaching approaches if underlying beliefs about content and the best suited methods to teach
63 content do not change among the teachers (Cohen & Yarden, 2009; Tidemand & Nielsen,
64 2017).

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65 The main tools for content selection are the available teaching materials, especially textbooks
66 (Remillard & Bryans, 2004; Shower, 2017; Spiegel & Wright, 1984). Among teachers, there
67 is a conflict between following the textbook's content and using them critically, as teachers
68 seem to understand critical reading of texts as distancing themselves from the text
69 (Loewenberg Ball, Feiman-Nemser, Ball, & Feiman-Nemser, 1988).

70 **Controversial and sensitive issues in teaching**

71 Real world applications of science commonly involve controversial issues, while, in general,
72 teachers are poorly prepared for teaching controversial issues (Oulton, Dillon, & Grace, 2004;
73 Oulton, Day, Dillon, & Grace, 2004) and especially less experienced teachers do not seem to
74 select topics that could be upsetting to students (Hess, 2008; Phillips, 1997).

75 Along the definition of Oulton, Dillon, & Grace (2004), we define controversial issues as
76 issues on which groups within society hold differing views based on different sets of
77 information or different interpretations from the available information due to their worldview,
78 such as different value systems. Sometimes controversial issues may be resolved by additional
79 information, but not always. For sensitive issues, we follow the ideas of Rowling (1996), who
80 suggests that the distinction between sensitive and controversial issues seem to be that
81 sensitive issues are connected to emotionality and the involvement of the individual.
82 Sensitivity can raise from political, religious, cultural, personal or gender reasons, but in
83 comparison to controversial issues, which by definition usually work on societal-level,
84 sensitive issues are more personal.

85 Arguably teacher beliefs are important factors in whether teachers embark on discussions of
86 controversial issues (Cotton, 2006). Most of the research on teaching controversial issues
87 have largely been in history and social science classes (i.e., Hess, 2008; Oulton et al., 2004a;
88 Oulton et al., 2004b) while sensitive issues are discussed in health and physical education

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89 (Lynagh, Gilligan, & Handley, 2010; Rowling, 1996). Science subjects are less studied, even
90 though they do not lack controversial or sensitive topics (Leonard, 2010; Levin & Lindbeck,
91 1979; Owens, Sadler, & Zeidler, 2017). In discussing controversial issues, teachers have
92 mentioned problems in beginning and maintaining discussions, dealing with students' "lack
93 of knowledge", insufficient teaching time, and scarcity of resources (Dawson & Venville,
94 2008; Dawson & Taylor, 2000; Hand & Levinson, 2012; Kuş, 2015; Reiss, 1999). One of the
95 solutions should be increasing teachers' confidence to implement teaching societally-relevant
96 issues, even though they could be controversial (Hofstein, Eilks, & Bybee, 2011).

97 Socio-scientific issues (SSI) have been suggested to empower students to reflect on the effects
98 and importance of genetics in the world around them (Lederman, Antink, & Bartos, 2014;
99 Lewis & Leach, 2006; Zeidler, Walker, Ackett, & Simmons, 2002). Nevertheless, teachers
100 have been resistant to adopt SSI in their teaching (Lazarowitz & Bloch, 2005; Lee,
101 Abd-El-Khalick, & Choi, 2006). Several reasons have been proposed to explain this
102 phenomenon, including limitations of the curriculum or assessment techniques, teachers'
103 pedagogical competence and that teachers lack of support for the merits of SSI discussions as
104 pertinent to specific learning subjects (Bryce & Gray, 2004; Gray & Bryce, 2006; Lewis &
105 Leach, 2006; Newton, Driver, & Osborne, 1999).

106 Content selection also seems to relate to the identity of the teacher. Albe and Simonneaux
107 (2002) used a theory of planned behavior (Ajzen, 1991) to approach this problem and they
108 revealed stark differences among teachers in different subjects and how teachers' attitudes
109 towards societal issues are shaped. The question of identity of the teachers, as experts in
110 biology versus experts in discussing human genetics seems to be one of the central problems
111 (Pedretti, Bencze, Hewitt, Romkey, & Jivraj, 2008; Tidemand & Nielsen, 2017). This seems
112 to also be reflected in the students: for example, in a Swedish study, upper-secondary school

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113 students majoring in science used few justifications from ethics or morality when discussing
114 GMOs (Christenson, Chang Rundgren, & Zeidler, 2014).

115 *Genetics contents and curricular development*

116 Genetics in secondary school biology curriculum has been emphasised in recent years, as the
117 progress in both basic science of genetics and the technological applications has been rapid.
118 This is likely to lead to both curricular renewal and the constant requirement of teacher
119 development. Choosing content for genetics courses poses a practical challenge for teachers
120 and fundamentally shows, what genetics could be seen as constitute of from a teaching
121 perspective.

122 There have been a number of endeavors to outline what would be the core (conceptual)
123 contents of genetics in different levels of lower and upper secondary school curricula.
124 Stewart, Cartier, & Passmore (2005) outlined that basic understanding of genetics requires
125 understanding three basic models: genetic (i.e., Mendelian inheritance patterns), meiotic (i.e.,
126 chromosome segregation and assortment) and biomolecular (i.e., genotype-to-phenotype
127 process). This was in turn refined by Duncan et al. (2009) who added environment as a
128 context and outlined their learning progression around two big ideas: 1) “All organisms have
129 genetic information that is universal and specifies the molecules that carry out the functions of
130 life. While all cells have the same information, cells can regulate which information is used
131 (expressed).” and 2) “There are patterns of gene transfer across generations. Cellular and
132 molecular mechanisms drive these patterns and result in genetic variation. The environment
133 interacts with our genetic makeup leading to variation.” In their Delphi study of genetic
134 literacy, Boerwinkel et al. (2017) furthermore added a difference between somatic and germ
135 line and polygenic inheritance to previous core contents and emphasized also sociocultural
136 and epistemic knowledge. In general, the diversification of core contents in genetics education

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137 from Mendelian genetics to polygenic traits seems to mirror the change in gene research
138 emphasis from quantitative genetics to genomics and whole-genome sequencing.

139 *Genetics in the Finnish upper-secondary school biology curriculum*

140 In Finland, approximately half of each age class enter general upper secondary schools, which
141 aims to both provide general knowledge required for an active participation in society and
142 prepare students for further education in tertiary level and working life. Finnish biology
143 teachers at upper secondary level have at least Masters level degree, including one-year of
144 studies in teacher education and one year of study in biology (see Niemi et al., 2012).

145 Finnish curricula tend to leave substantial freedom for teachers to interpret the educational
146 aims and develop multiple different methods to implement curricula. Finnish teachers plan
147 teaching according to local curricula, which are formulated by the education providers and
148 schools based on the national core curriculum for general upper-secondary schools (FNBE,
149 2003) The core content pertaining to genetics is mostly limited to two courses: Cells and
150 heredity (BI2), which is mandatory for all students, and Biotechnology (BI5), which is an
151 optional course in the biology curriculum (Table 1).

152 [Table 1 here]

153 While teachers' practices and attitudes towards different teaching approaches and methods
154 have been widely studied in science education (e.g., Lederman & Abell, 2014), there is far
155 less research on what contents and examples teachers choose for their teaching and how they
156 justify their choices for instance in an upper-secondary school biology course. As the Finnish
157 school framework provides for ample freedom for teachers to adopt the most suitable teaching
158 methods and biology teachers are generally educated broadly in different fields of biology,
159 this allowed us to explore the curricular genetics contents the teachers emphasize in their
160 teaching and what are teachers' perceptions of controversial and sensitive issues in genetics.

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161 We used interviews to examine teachers' answers to questions about how they use three
162 different human-related contexts in their teaching: genetically modified organisms, human
163 hereditary disorders and complex human traits, such as intelligence. The first context, GMOs,
164 is explicitly mentioned in the national core curriculum, and teachers must discuss the ethics of
165 GMOs. The second context, hereditary disorders, is not mentioned in the curriculum, but most
166 known examples of Mendelian genetic traits in human context are hereditary disorders.
167 Thirdly, complex human traits, like intelligence, are not mentioned in the curriculum, but this
168 context can be used to discuss polygenic inheritance. Thus, these contexts differ in how easy
169 it is to avoid using them: while avoiding GMOs is not possible for teachers, complex human
170 traits can be easily avoided.

171 Our research questions were:

- 172 1. What do teachers perceive as the main contents of genetics teaching in the upper
173 secondary school in biology?
- 174 2. How teachers argue for their use of human-related contexts in genetics teaching?
- 175 3. What kind of controversial or sensitive issues do the teachers consider when teaching
176 of genetics?

177 **Methods**

178 Our research design was a qualitative case study. We conducted open-ended semi-structured
179 interviews with 10 upper secondary high school biology teachers from various schools from
180 Southern and Western Finland between 2015 and 2016 (see Table 2). Teachers were selected
181 purposively to reflect a variation in experience, gender, type of school and geographical
182 location in order to access different teachers with knowledge about upper secondary school
183 biology education. All teachers had biology as a major subject in their university master's

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184 degree. Additionally, we collected diary data and other teaching materials from teachers how
185 they actually teach genetics.

186 *Interviews*

187 The interviews lasted from 40 minutes to 1 hour and 32 minutes. Teachers were asked: a)
188 what they perceive as the most important contents and contexts in genetics, b) how they
189 acquire knowledge for teaching and c) what examples they use during the two courses, BI2,
190 for Cells and heredity course for all students, and BI5, a Biotechnology optional course (Table
191 1). Especially, we asked how teachers teach the topic of GMOs in the BI5 course and what
192 kind of examples of human genetics they use in courses BI2 and BI5.

193 Our aim was to find out how teachers justify their content and context choices in genetics
194 teaching. We used a theory-guided content analysis to categorize the data in a six-stage
195 process by following the ideas of abductive analysis laid out by Timmermans and Tavory
196 (2012): 1) we transcribed the interviews; 2) we coded the transcripts one sample at a time by:
197 a) which subject matter teachers thought was the most crucial and which could be left aside,
198 b) how they argued for including or excluding certain course content and c) how they
199 described what they feel students feel important; 3) beginning from the first sample, we
200 named concepts arising from the grouped codes and after each sample, recursively performed
201 stages 2 and 3 for previously-coded samples (which would correspond to initial analysis as
202 per Charmaz (2003); 4) after initial samples were coded and concepts named, we integrated
203 categories (focused analysis); 5) we contrasted the teachers to each other to understand the
204 connections between categories, and 6) we refined the model. We used the R (R Core Team,
205 2013) package RQDA (Huang, 2017) for the analysis.

206 We contrasted the emerging codes with the assumption that teachers' content and context
207 choices are guided by national and local curriculum, teaching materials and teachers' personal

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208 knowledge. When coding content choices, three different groups emerged: monohybrid
209 crosses in humans, polygenic properties of humans and GMOs. Within these three groups, we
210 coded on later recursions all the mentions of the issues the teachers described that a) they use
211 in teaching, b) they avoid using in teaching, c) the topics in which the students express
212 interest, and d) topics in which the students express no interest in. We then simplified
213 authentic expressions in the open codes to a combinations which would describe general-level
214 biological phenomena, such as evolution, inheritance or gene expression. After half of the
215 samples were coded, selective coding was used to delimit the coding process. Purposive
216 sampling fitted well this research approach as our data was rather rapidly saturated: by the
217 ninth sample, there was no new information useful for the category formation. After the
218 analysis process, we asked teachers whether they agree on our analysis of the emphasis of
219 their teaching.

220 *Trustworthiness*

221 To assess the connection between descriptions that the teachers gave of their teaching during
222 the interviews and their actual teaching, we asked the teachers to keep diary of their teaching
223 after the interviews. We suggested that teachers write down for each lesson the topics,
224 teaching methods, which textbook chapters and exercises were discussed and on which topics
225 the students asked questions or clarifications. Additionally, teachers who had ready-made
226 lecture slides sent those to us. An outside observer and first author classified diaries and other
227 materials based on previously formed classifications (Table 2), which allowed us to compare
228 teachers' interviews and actual teaching.

229 We continuously evaluated the trustworthiness for our study in several ways (Morrow, 2005).
230 During the category formation, we looked for disconfirming data and assessed data saturation.
231 The credibility was also enhanced by continuous discussion and revising the meanings and
232 coding of the data during the categorization by the first author and the transcriber, who was a

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233 sociolinguist. Transferability was improved by a rich description of the research process in the
234 form of an audit trail. Audit trail was drafted based on the memos and the developed coding
235 schemes. The authors evaluated the audit trail and agreed with research process.

236 [Table 2 here]

237

238

Findings

239 *What do teachers perceive as the most important content in genetics courses?*

240 When we asked teachers to summarise what they hoped students would learn from upper-
241 secondary school biology courses, the teachers mentioned different contents (Table 2, Table
242 S1). We divided their answers to three distinct themes: 1) development of phenotype, 2)
243 inheritance and continuity and 3) the structure and function of the genes. Some teachers gave
244 several descriptions that fitted two of these themes, but none described all three.

245 The first theme, development of phenotype, contains descriptions that focused on
246 understanding how genes and environment shape the development of different traits (i.e.,
247 genetic determinism). These descriptions were often related directly to how students
248 themselves have developed and to understanding of how human individuals have formed:

249 Teacher J: “Humans are constructed by many factors, of which genome influences
250 greatly, or they are things which we cannot influence ourselves; they come directly
251 from the genome, but also genes do not dictate how we live our lives, what kind of
252 persons we are, and how we behave.”

253 The second theme, inheritance and continuity, is centered on the concept that there is genetic
254 continuity in the tree of life and that DNA copies itself from generation to generation.

255 Teachers who described concepts relating to this theme saw the understanding of evolution as

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256 the focal point of whole field of biology and saw genetics as central to this understanding.

257 Biodiversity was mentioned as one manifestation of this continuity. Sometimes the

258 descriptions of the most important ideas were affective:

259 Teacher C: “The common thread of life, from the beginning, the same genes are
260 flowing; we are composed of genes from a million persons from thousands of years
261 and then a new combination pops up, from the stream of life.”

262 The third theme, the function of the genes, was the simplest theme in terms of how teachers
263 described it. They usually said that it was important to understand what genes are and how
264 they function, while offering no reference to any reason why it is so. Some teachers
265 mentioned that it is important in terms of general knowledge to know these topics.

266 Teacher B: “If I say it concisely, what is the gene and how does it function is the core
267 knowledge a student should have.”

268 *Use of human-related contexts in genetics teaching*

269 *GMOs*

270 Most of the teachers approached ethical questions as being superimposed on the biological
271 content within a course and they thought the students should know the biological contents of
272 GMOs before discussing their ethical dimensions (Table S2). Some teachers also suggested
273 that students have highly polarised opinions on GMOs before coming to a course and that
274 “knowledge” could help in seeing the different aspects of the debate.

275 Teacher F: “We have two types of students, so that they are pretty black-and-white.
276 Some of them have already been kind of brainwashed to think that “this is all great”,
277 while a minority, or I don’t know if they don’t just dare to tell me, are against GMOs.”

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278 Three teachers said that they use SSI as a means to motivate students in the beginning of the
279 course, while the other seven said that they first teach the biological content and then move to
280 ethical discussions. Still, ethical questions were seen as secondary to biological content:

281 Teacher J: "...there's not always much time for discussions – the time spent in ethical
282 discussions is always reduced from less than what is spent on the course texts."

283 *Human genetics*

284 Teachers mentioned that the use of human examples in genetics is mostly limited to
285 Mendelian disorders in BI2 course (Table 2, Table S3) and more complex traits are then
286 discussed at the end of BI2 or during the BI5 courses (Table 2, Table S4). Teachers
287 commonly held the opinion that students are interested in hereditary phenomena in general
288 (Table S5), but there is mismatch in how textbooks frames genetics and what the students'
289 interests are: while students are mainly interested in human genetics, the textbooks lack good
290 examples and teachers did not feel themselves competent to go deeper into the topic:

291 Teacher J: "... [student asks] if I have blue eyes and my boyfriend has brown eyes,
292 then what color will our children's eyes be, but unfortunately I have to try to contain
293 their excitement as I don't know the answers to their questions."

294 Some teachers mentioned that they use classic, if not the most correct, examples like a
295 widow's peak or rolling the tongue. All teachers who used these examples said that,
296 nevertheless, they mention to students that in reality, genetics is not that simple.

297 Two teachers mentioned that they try to avoid human context in general and three other
298 teachers said that they try to avoid discussing complex human traits, such as talent,
299 intelligence, or human behavior (Table 2, Table S6):

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300 Interviewer: Do you discuss how genetics affects learning? What if some students
301 have genes that allow them to achieve better grades?

302 Teacher E: No, no. (pause). No.

303 Interviewer: No?

304 Teacher E: No, we don't discuss that.

305 Interviewer: No one is interested?

306 Teacher E: No. I'm not interested either (laughs)

307 *Interviewer laughs*

308 Teacher E: I think it is very sensitive issue. I would reconsider several times before
309 talking about it.

310 Most teachers said that they discuss human behavioral genetics if students ask questions, but
311 they do not bring the topic up themselves. In contrast, some teachers said the discussions are
312 needed, especially in the context of racial issues:

313 Teacher D: "It is relevant for the students if it is discussed in public, societal debate –
314 [they may want to know if] citizens from certain continents are less intelligent than
315 others–, and we have discussed these alternative news a lot, how they publish utter
316 nonsense."

317 *Controversial or sensitive issues in genetics*

318 Half of the teachers did not identify any sensitive or controversial issues, which they would
319 avoid (Table 2, Table S6). Among the other half there were differences in how they framed
320 sensitive and controversial issues. Most of the argumentation was related to what is seen as
321 biological general knowledge or avoiding misconceptions on genetics: teachers mentioned or

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322 implied that complex human traits are inherently so complex that there is a significant risk
323 that students would form misconceptions on overtly genetic determinations of these traits.
324 Furthermore, the lack of examples and lack of teacher competence was seen as leading to
325 teaching without meaningful contents. The two teachers who avoid humans as a context
326 argued that humans are just one species, and it is not meaningful to concentrate too much on
327 humans in biology.

328 Additionally, teachers mentioned how some issues are uncomfortable to them or to their
329 students. Regarding students, some teachers acknowledged that discussing human heredity
330 can pose several challenges (Table 2, Table S6). For example, using blood group testing can
331 raise questions and even distress students if their blood group is not concordant with their
332 parents' blood groups. One teacher mentioned she does not want to do pedigrees on simple
333 traits with students because of the “diversity of families” and her not knowing the
334 backgrounds of the students. The reason for describing these issues as “uncomfortable” was
335 framed as a question of teacher not knowing how to deal with discussing these issues or
336 encountering unexpected reactions from the students. Those teachers willing to discuss
337 genetic disorders of students or their families argued that generally those affected know best
338 about the issues. One teacher also mentioned that sensitive issues bring up emotions, but that
339 it is also natural in a classroom setting:

340 Teacher C: “Sometimes I’ve gone and hugged a student – I find it a good way to calm
341 down. – Every now and then I have tears in my eyes, but I think it’s important to show
342 my own persona in my teaching.”

343 *Teachers frame genetics teaching with different emphases*

344 Teachers' perceptions of the most important genetic content were closely related to their
345 willingness to use human context in their teaching or even what they said that students find

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346 interesting (Table 2). For example, none of the teachers whose theme in genetics teaching was
347 classified as “development of phenotype” mentioned that they try to avoid human complex
348 traits. In turn, both teachers who said that students are interested in gene testing had their
349 theme grouped to “inheritance” and both teachers who mentioned students are interested in
350 epigenetics to “development of phenotype.”

351 Three different general frameworks of teaching genes and their role arose from the analysis:
352 *Developmental*, *Structural* and *Hereditary* (Table 3). We call these emphasis of contents in
353 genetics teaching, as they relate to how teachers argue for their choice of contents and which
354 they see as the most important contents or themes, but also which contexts they use, how they
355 perceive student interest and whether they avoid certain topics. Furthermore, they align with
356 perception of sensitive or controversial issues. We note that these emphases do not consider
357 how teachers understand genes or their function, but rather what teachers see genetics to
358 constitute of from a teaching perspective.

359 A *Developmental* emphasis frames the development of traits as the central theme in genetics
360 and consequently teachers who used this approach were largely open to any discussions, they
361 did not mention any topic they would avoid, and most of them mentioned that they have
362 regular discussions about complex human traits as they felt that students are most interested in
363 these. Furthermore, teachers with *Developmental* emphasis were less likely to describe any
364 perceived sensitive issues than other teachers (Table 2). These teachers were all
365 comparatively the less experienced teachers of the interviewed group (12 or fewer years of
366 experience). Their emphasis contrasts with two teachers who used a *Structural* emphasis
367 mentioning only gene function as the central issue. These teachers mentioned avoiding
368 discussing complex traits in humans or humans at all, as they find these both sensitive and not
369 good examples of polygenic inheritance. In contrast, these teachers described hereditary
370 analysis as an interesting part of the genetics course. They were among the most experienced

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371 teachers (> 20 years). A third emphasis, *Hereditary*, was characterised by emphasis on the
372 continuity of DNA through the whole tree of life. This emphasis manifested in teachers'
373 answers as being somewhere between the two previous emphasis. Teachers which used this
374 emphasis were willing to discuss complex human traits if the students asked about them, but
375 did not actively raise examples. They generally used an example of human skin color as an
376 example of polygenic traits. More broadly, in genetics, they usually emphasised the
377 understanding of phenomena related to DNA duplications, such as meiosis. A hereditary
378 emphasis was used by both less and more experienced teachers.

379 [Table 3 here]

380 In contrast to the issues involving the human complex traits, genetics content emphasis were
381 not connected how teachers taught GMOs (Table S2). While some teachers were more
382 dismissive about teaching on SSI while discussing GMOs, and said that there was not always
383 time to go through those topics, they were not differentiated based on their genetics emphasis.
384 Furthermore, one teacher who said that they use GMOs as a motivation in the beginning of
385 the course, to explain how genetics are important, said that they do not always have time to go
386 into ethics of GMOs. In general, lack of time is a general perception of teachers in different
387 subjects and countries (Adams & Krockover, 1997; Archbald & Porter, 1994; Fuller, 1969)
388 and the interviewed teachers also expressed this idea repeatedly. This reason worked in
389 concert with the acknowledgement from most teachers that their teaching closely follows to
390 the textbook, and textbooks tend to discuss ethical dimensions of biotechnology at the end of
391 the book (Aivelo & Uitto, 2015).

392 *Teacher self-identification and relationship to actual teaching*

393 When we provided teachers with the descriptions of the genetics emphasis and our analysis of
394 their interview, six teachers agreed with our analysis, three teachers disagreed and we could

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395 not contact one teacher (Table 2). All disagreeing teachers had their teaching emphasis
396 labelled to Developmental. Two of the teachers also argued for that their emphasis was not
397 the one they would have preferred for genetics teaching, but it was mostly dictated by national
398 curriculum, which mentions evolution and development in different courses.

399 We obtained teaching diaries and other teaching materials with enough information for our
400 analysis from five teachers. In categorization, the interrater reliability was high (Cohen's
401 kappa: 0.88). The concurrence between interviews and diaries was variable as some teachers
402 were fully concordant (such as teachers B and H), whereas Teachers G and J had two
403 discordant categorizations (Table S7). In total, 18 of 22 analysing units were concordant
404 between the interviews and diaries.

405 *Factors behind teachers' choice of content*

406 Although there were large differences in teachers' emphasis in genetics teaching, there were
407 some similarities in their arguments on factors influencing their content choices (Table 2).
408 While the teachers described their teaching in very different terms, all expect teacher E said
409 that 1) they follow closely the textbook content. Because the contents of biology textbooks for
410 upper-secondary school is highly similar (Aivelo & Uitto, 2015), teachers clearly had
411 different personal priorities on the most important contents and contexts. All schools follow
412 2) the national core curriculum (FNBE, 2004), and this was evident in teachers' descriptions
413 of their content choices (Table 2, 3). Furthermore, this was emphasised by the inclusion of
414 GMOs in the biology core curriculum by all teachers (Table 3). The national core curriculum
415 is also the basis for the tasks on the matriculation examination that the students take in the end
416 of the upper secondary school in Finland (Niemi et al., 2012) and teachers acknowledged that
417 3) previous exam questions guide their teaching.

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418 The aforementioned factors were quite similar for each teacher, but our results also reveal
419 perceived differences among teachers and the 4) school-specific circumstances in which they
420 are working. Some of the teachers compared their school to other schools, and suggested that
421 some attributes of their school attract students with specific interests or motivation or
422 competence to study biology. Likewise, teachers described differences in course
423 arrangements, and noted if it was possible to conduct experiments in the classroom.
424 Furthermore, teachers expressed that there are 5) personal reasons that affect their course
425 content selection. On many occasions the teachers acknowledged the limits of their
426 competence, either regarding genetics contents, such as when they are unable to answer
427 complicated questions of the students, or pedagogically, when they mentioned they might
428 have problems in successful guiding of classroom discussions.

429 **Discussion**

430 *Teachers' emphasis in genetics*

431 Our findings suggest that there were fundamental differences in Finnish upper secondary
432 school biology teachers' perceptions on the most important themes in genetics and genetics
433 teaching and subsequently how they chose course content and context while teaching
434 genetics. The perceptions can be classified to three distinct content emphasis, which we
435 named *Structural*, *Hereditary* and *Developmental*. These emphases are formulated on the
436 basis of what teachers interpret as 1) the central themes in genetics, 2) how they use human
437 contexts in their genetics teaching, 3) how they understand students' interest towards different
438 contents and contexts and 4) whether they perceive genetics include sensitive or controversial
439 issues.

440 Our findings are partly similar to those of Van Driel et al. (2007), who found separate
441 subgroups of teachers who teach either subject-matter oriented focusing on fundamental,

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442 theoretical concepts or learner-centered emphasising societal issues. While *Structural*
443 emphasis can be seen as subject-matter oriented, *Developmental* emphasis is not learner-
444 centered in similar sense as in Van Driel et al.'s study, as the orientation is not as much
445 societal as it is personal. Stewart, Cartier and Passmore (2005) outlined three different models
446 of genetics understanding: inheritance pattern model, meiotic model and biomolecular model.
447 These models are quite close to our concept of content emphasis: inheritance patterns model
448 and *Hereditary* emphasis are similar and *Structural* resembles meiotic model while
449 *Developmental* has less common with biomolecular model.

450 The diversity of emphases can be explained, for example, with complex educational context
451 in Finnish upper secondary school. Finnish upper secondary school aims to train students for
452 tertiary education, but also to develop scientific literacy to those students who do not study
453 biology further. The biology course "Cells and heredity" is compulsory to all students of
454 which approximately one third complete biology part of matriculation examination
455 (Matriculation Examination Board, 2019). Thus, the teachers are balancing with what Roberts
456 (2007) referred to as vision I (as knowledge within science) and vision II (as knowledge in
457 everyday situations) of the scientific literacy.

458 Moreover, genetics content emphasis can be seen as partly overlapping with "science teaching
459 orientations" (Magnusson, Krajcik, & Borko, 1999) as they contain knowledge of the
460 importance of different concepts, interpretation of curricula, the motivations of the students,
461 and representations and context of core concepts. In comparison, while the science teaching
462 orientations describe teachers' perceptions about teaching and especially instruction methods,
463 we did not find that genetics content emphasis would limit the instruction methods.
464 Nonetheless, the different emphases raises the question of how differential teacher
465 understanding of core concepts and contexts influences teaching methods or orientations to

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466 teaching science. In a follow-up study, we aim to study teachers' gene concepts and whether
467 they relate to different emphasis.

468 *Human-related contexts involve controversial and sensitive issues*

469 Our research setting in comparing three different human-related contexts - GMOs, Mendelian
470 human traits and complex human traits - contrasts the effects of curriculum-dictated context
471 choice and free choice by teachers, and highlights the difference between personal and
472 societal relevance. Our interviews showed a paradoxical approach by teachers: while they said
473 that genetics is a societally relevant topic, and that students should learn analytical tools to
474 take part in decision-making and be responsible consumers, this was not evident in their
475 descriptions of their teaching. Without exception, teachers formulated the basic science as the
476 main issue and, in many cases, societal aspects of GMOs were described to be taught only "if
477 there was time at the end of the course." Our results agree with Tidemand and Nielsen's
478 (2017) suggestion that emphasis on biological content (as opposed to more societal context) is
479 driven by teachers' identity as biology teachers. Nevertheless, all teachers did teach GMOs as
480 they are explicitly mentioned in national curriculum.

481 In comparison, some teachers described avoiding human genetics contexts which could be
482 seen as personally highly relevant to students. These teachers were also more likely to
483 describe controversial or sensitive issues related to genetics teaching. It is noteworthy, that
484 teachers framed sensitive issues in human genetics in relation to students personally, as
485 something which concerns individual students and not as much society at large. Thus, in
486 Rowling's (1996) categorization, the teachers were more worried about sensitive issues than
487 controversial issues. Furthermore, this suggests that there is a trade-off between personal
488 relevance to students and perceived problems arising from sensitive issues. As this was not
489 mentioned in relation to GMO teaching, teachers seem to be more hesitant towards this
490 personal relevance, rather than societally controversial issues.

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491 The avoidance of human contexts is a complex issue as teachers used numerous reason for
492 steering clear, for example, human genetics: a) students are not interested in these topics, b)
493 teachers do not have enough content knowledge, c) teachers do not have pedagogical
494 knowledge for teaching sensitive issues and d) discussing genetics in human context would
495 lead to negative learning outcomes, such as misconceptions. In general, controversial issues
496 were thought to lead to misconceptions, whereas sensitive issues were seen to lead to
497 awkward situations for individual students. We are not able to assess how relevant these
498 different factors are, but it is clear from our content emphasis classification that there are
499 fundamental differences in how teachers perceive the most important contents and contexts in
500 genetics. Furthermore, contrary to the previous studies (Hess, 2008; Phillips, 1997), our study
501 suggests that Finnish teachers are open to discuss complex human traits and other sensitive
502 issues in classroom even when they are not experienced.

503 *Limitations of the study*

504 While the number of interviews in our study is limited, we reached data saturation rapidly.
505 One reason for this may be the similarities in the educational background of the teachers, as
506 all of them had master's degree with biology as the major subject, and pedagogical studies in
507 teacher education as a minor subject. Moreover, the textbooks used by the teachers are quite
508 similar, emphasizing gene structure and function (Aivelo & Uitto, 2015). Due to small
509 number of participants and limited knowledge on teachers' background, we cannot discuss
510 other factors than those mentioned by the teachers: namely, the role of used textbooks,
511 biology curriculum, practicing for the matriculation examination and school-specific and
512 personal factors. The interpretive disagreements on genetics content emphasis between some
513 teachers and researchers were all related to *Developmental* emphasis. Nevertheless, the
514 interrater reliability in categorization and the concordance between teacher interviews and
515 diaries was rather high.

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516 Potential sources of bias were minimized by allowing the interviews to be as freely advancing
517 as possible and questions were designed to prevent confirmation bias by probing for
518 disconfirming answers and leading questioning by starting each strain of questions by as
519 general questions as possible. Research positionality was reflected regularly through
520 interactions between the authors and in discussions with outside researchers and biology
521 teachers. The authors have multi-faceted relationship towards participant community as they
522 are involved in teacher education and in-service teachers' continuing education and both have
523 background as upper secondary school biology teachers. Both authors have also been
524 involved in national core curriculum process. Thus, the authors are insiders in the participant
525 community but also hold positions of power. This setting was approached by emphasizing to
526 teachers that they are experts in teaching practice and that the researchers were genuinely
527 interested on their answers.

528 *Implications for research and teaching practice*

529 National curriculum for upper secondary schools gives a substantial freedom to teachers to
530 interpret the contents and goals of biology education in classroom practice (FNBE, 2004;
531 Niemi et al., 2012). This may partly explain the fundamental differences in content emphasis
532 that we found. Consequently, in school practice, teacher education, and in-service training, the
533 teachers should be made more aware and provide opportunities for self-reflection on the
534 emphasis they take in teaching science.

535 We also suggest that our findings on which contents teachers choose for their teaching
536 provides a well-grounded hypothesis for further research on the content perspective of
537 experienced, autonomous biology teachers. The relationship between content emphasis and
538 the choice of course content could provide a more widely applicable hypothesis for studying
539 teaching and learning genetics in biology education, because teachers have freedom to choose
540 whether or not to apply sensitive human context to their teaching.

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541 In light of GMO SSIs being integrated in the teaching, independent of teacher inclinations, we
542 suggest that the curriculum development would be valuable approach if genetics education
543 aims to better incorporate societal and personal relevance. Furthermore, curriculum
544 development needs to be connected with teacher education emphasizing pedagogical content
545 knowledge (Käpylä, Heikkinen, & Asunta, 2009). While teachers appreciate a “knowledge
546 first” approach to SSI and avoidance of human related topics, there is a perceived lack of
547 useful and tested teaching materials. Content knowledge is important for successful reasoning
548 regarding SSI: thus, a delicate balance needs to be sought (Lederman et al., 2014; Sadler &
549 Zeidler, 2004)

550 From our interviews, it is clear that the personal relevance in teaching can be a double-edged
551 sword in the classroom: while some teachers see it as a possibility, some seem to avoid it due
552 to a number of reasons. This needs to be addressed more in professional development. In
553 general, the ways of teaching controversial and sensitive issues are not well-studied and the
554 recommendations themselves are controversial (Christopher Oulton et al., 2004). Thus, both
555 societal and personal relevance should be taken more into account in science and especially in
556 biology teacher education and in-service training.

557 **Conclusions**

558 Based on qualitative case study and teacher interviews, we have found that teachers’
559 perceptions of genetics teaching reflected three different emphases, which we named as
560 *Structural, Hereditary, or Developmental* content emphasis. These emphases consists of
561 teachers’ perceptions of the most important themes in genetic content, willingness to teach
562 about human traits, perceived sensitive or controversial issues in genetics and students’
563 perceived interests. Interestingly, teachers having *Structural* emphasis described avoidance of
564 human genetics context in their teaching, while teachers with *Developmental* emphasis
565 described very abundant use of human genetics contexts. Thus, teachers’ perceptions of which

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566 themes in genetics are the most important could also shape how likely they are to use
567 personally relevant contexts in their teaching. As we did not observe the actual teaching
568 practice, we do not know how well these emphases manifest in teaching itself and whether
569 these have an actual effect on student learning outcomes. Our ongoing research project could
570 shed light in this by comparing student interests and attitudes to their teacher's genetics
571 content emphasis. Nevertheless, we suggest that teachers' perceptions on the most important
572 themes in their teaching can have wide-ranging consequences, for example, inclusion of
573 socioscientific issues in the teaching.

574 Our results also revealed different approaches to the sensitive and controversial issues in
575 genetics teaching. Not all teachers perceived that sensitive or controversial issues would affect
576 their teaching and those who did, usually describe sensitive rather than controversial issues,
577 thus suggesting that teachers are more worried about personal issues in genetics. Indeed,
578 sensitivity was sometimes used as a justification to not include contents or contexts which are
579 personally relevant to genetics teaching. We note that teachers would need more support to
580 handle controversial and sensitive issues in the classroom. In contrast to personally relevant
581 human genetics, Finnish curriculum specifically mentions GMOs and compels teachers to
582 discuss them. Subsequently, every teacher mentioned that they discuss GMOs. Thus, we also
583 argue that curricular development is an effective way to increase the prominence of societal or
584 personal relevance in biology education.

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592

Appendix

593 Supplemental material in Figshare (doi: 10.6084/m9.figshare.8427056) includes following
594 tables containing representative quotes from teacher interviews:
595 Table S1: Teacher's descriptions of the central theme of their teaching.
596 Table S2: Teacher's descriptions of GMOs in their teaching.
597 Table S2: Teacher's descriptions of the human Mendelian disorders in their teaching.
598 Table S3: Teacher's descriptions of the complex human traits in their teaching.
599 Table S5: Teacher's descriptions of the perceived student interest in genetics.
600 Table S6: Teacher's descriptions of perceived sensitive issues.
601 Table S7: The concurrence between teaching diary and other materials in comparison to
602 teacher interviews.

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HOW DO TEACHERS CHOOSE CONTENT FOR TEACHING?

764 Table 1: The Core content described in the Finnish national curriculum with selected parts
765 from courses BI2 and BI5

Topics	BI2—Cell and genetics <i>Mandatory course</i>	BI5—Biotechnology <i>Optional course</i>
DNA and genes	DNA structure and function Genes and alleles Protein synthesis	DNA, gene and genome structure Gene function and regulation
Cell functions	Gametes and meiosis Mitosis	
Inheritance	Inheritance mechanisms Population genetics	
Applications		Gene technology
SSI		Ethics and legal issues in gene technology

766 Table 2: Summary of interviews of ten interviewed teachers. For details, see the supplemental material.

Teacher	Gender	Central theme of teaching	Examples of Human Mendelian traits	Examples of Complex human traits	Perceived controversial or sensitive issues	Perceived student interest	Genetics content emphasis	Teacher concurrence with analysis
A	Female	Development of phenotype	Disorders, lactose intolerance	Life style diseases	None	Artistic talent, epigenetics	Developmental	Yes
B	Male	Development of phenotype	Disorders, blood groups, tongue roll	Height, skin colour, talent	None	Epigenetics, talents, monohybrid crosses	Developmental	Yes
C	Female	Inheritance and continuity	Disorders	Eye color, generally avoid	Intelligence	Gene tests	Hereditary	Yes
D	Male	Inheritance and continuity	Disorders	Height, skin colour	Human race-related	Medical genetics	Hereditary	No answer
E	Male	The structure and function of genes	Eye colors, generally avoid	Shoe size, generally avoid	Intelligence	Mono- and dihybrid crosses	Structural	Yes
F	Female	Development of phenotype	Disorders, tongue roll, widow's peak	Height	None	Challenging contents	Developmental	No; Structural
G	Female	The structure and function of genes	Tongue roll, eye colors, generally avoid	Height, hair coloration, generally avoid	Intelligence, talent, genetic disorders	Mono- and dihybrid crosses	Structural	Yes
H	Female	Inheritance and continuity	Tongue roll, ear lobe	Skin color, generally avoid	None mentioned	Inheritance patterns	Hereditary	Yes
I	Male	Development of phenotype	Disorders	Stress reaction, intelligence	None	Sex-related traits	Developmental	No; Structural
J	Female	Development of phenotype	Disorders, eye colour, ear lobe	Height, skin colour	Developmental disorders	Musicality, own complex traits	Developmental	No; Hereditary

Running head: HOW DO TEACHERS CHOOSE CONTENT FOR TEACHING?

767 Table 3: Three different content emphasis and the teacher perceptions and descriptions which
 768 differ between emphasis.

Content emphasis	Structural	Hereditary	Developmental
<i>Central theme</i>	Gene structure and function	Continuity of DNA through time	Development of traits
<i>Human context</i>			
1. Human Mendelian disorders	Avoid	Use as examples	Use as examples
2. Complex human traits	Avoid	If students ask	Use as examples
<i>Perceived student interest</i>	Monohybrid, dihybrid crosses	Gene tests, medical genetics	Epigenetics, complex human traits

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