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RELATIONSHIPS AMONG TURKISH PRE-SERVICE SCIENCE TEACHERS' GENETICS LITERACY LEVELS AND THEIR ATTITUDES TOWARDS ISSUES IN GENETICS LITERACY

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Abstract. *The importance of genetically literate individuals who can understand and join debates about genetics related issues, including gene therapy or cloning has been acknowledged by societies. With this respect, raising genetically literate individuals has become more prominent. Teachers' knowledge in genetics literacy and their attitudes towards issues in genetics literacy influence their teaching practices. As a wide range of variables effect teachers' genetics literacy levels and attitudes, this study examined how a set of variables including pre-service science teachers' self-perceived interest, knowledge and importance of genetics, gender, academic achievement, socioeconomic status (household income, employment status and educational level of parents) are related to the their genetics literacy levels and attitudes towards various genetics literacy issues. Data was collected from 355 pre-service science teachers through administration of Genetics Literacy Assessment Inventory and Attitudes towards Issues in Genetics Literacy Scale. Canonical correlation analysis suggested that self-perceived interest and importance in genetics literacy issues, gender and parents' educational levels were positively associated with participants' genetics literacy levels, as well as attitudes towards the use of genetic information, gene therapy, and gene therapy applications. On the other hand, self-perceived knowledge, GPA, household income, employment status of parents were not found to be associated.*
Key words: *genetics literacy, pre-service science teachers, attitude, socio-demographic variables.*

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Introduction

Genetics and genetics related issues become an indispensable part of our everyday life in parallel with technological advances. Thus, these issues have become more prominent and have an increasing impact on modern societies (Klop & Severiens, 2007). This increasing impact, in turn, has also evoked public attention and led to a series of debate regarding applications of various genetics technologies, including genetic testing, stem cell research, cloning, gene therapy or genetically modified foods (Boerwinkel, Swierstra, & Waarlo, 2014; Concannon, Siegel, Halverson, & Freyermuth, 2010). Connected with this, not only developing understanding but also participating in and making informed decisions about science-based social discussions turn out to be a requirement for citizens in modern societies (Eggert & Bögeholz, 2010; Kolstø et al., 2006; Lee, 2007; Lewis & Leach, 2006; Norris & Philips, 2003; Tytler, Symington, & Smith, 2011). With this respect, young people should be prepared for their roles as active citizens of societies in future by being aware of the public debates such as privacy of biomedical and personal information, use of genetic databanks or potential benefits and the risks of gene technologies as well as being able to take part in resolution of these debates (Dawson, 2007; Miller, 1998; Norris & Philips 2003; Tytler et al., 2011). The aforementioned debates posed by new genetic technologies emphasize a relatively new terminology called "genetics literacy" which can be defined as having necessary knowledge in genetics, and using this knowledge to make informed decisions for personal well-being which in turn, resulted in effective participation of social issues (Bowling, 2007). The critical function of genetics literacy is to focus on the collective consciousness of the individuals about genetics related issues, and debate with other members of the public about the genetics applications (Acra, 2006; Jennings, 2004).

With the rapid developments in the area of genetics research, public show reactions, including mixed feelings which require an understanding of

these issues (Knippels, Severiens, & Klop, 2009). Emerged as a public demand, it is important to raise genetically literate individuals who have the critical ability to understand genetics concepts to make informed decisions related to genetics applications by considering ethical, legal and social implications of genetics related issues (Bowling et al., 2008a; Dawson, 2007; Dawson & Schibeci, 2003; Klop & Severiens, 2007; Lanie et al., 2004; McInerney, 2002). For raising genetically literate individuals, on the other hand, school science should provide appropriate context that learners can develop an understanding and decision making skills for identifying ethical dilemmas, defining the views for and against the different decisions, deciding what should be done and justifying their views which will be resulted in developing affective reaction (Dawson, 2003; Klop & Severiens 2007; Klop, Severiens, Knippels, van Mill, & Ten Dam, 2010; Venville & Dawson, 2010). The inclusion of genetics literacy issues into science classes will prepare students for their future roles as Levinson (2006) indicated. At this point, teachers' role of implementing genetics literacy issues is crucially important. Even science teachers are assumed to be real implementers of issues in genetics literacy, research studies conducted in different countries indicated teachers' unwillingness to implement these issues into their classes (e.g., Borgerding, Sadler, & Koroly, 2013; Eggert & Bögeholz, 2010). This can be attributed partly to teachers' difficulty in subject matter knowledge regarding controversial issues in genetics (Steele & Aubusson, 2004), lack of their confidence in handling discussions related with controversial issues in their classes (Bryce & Gray, 2004) and partly to curricular restrictions and external examinations (Eggert & Bögeholz, 2010; Lazarowitz & Bloch, 2005), and lack of time and resources (Bryce & Gray, 2004; Kwon & Chang, 2009; Zeller, 1994). Overall, the reported factors, including lack of subject matter knowledge, lack of confidence, time, and resources, as well as curricular restrictions and external examinations could impede teachers from effective teaching of issues in genetics literacy.

Close examination of related literature implied that socio-demographic characteristics, including gender, level of education, self-perceived interest, religious affiliations, and cultural factors, also have an impact on individuals' attitudes towards different issues in genetics literacy (Brossard, Scheufele, Kim, & Lewenstein, 2008; Črne-Hladnik, Hladnik, Javornik, Košmelj, & Peklaj, 2012; Hagay et al., 2013a; Hagay, Peleg, Laslo, & Baram-Tsabari, 2013b; Sohan, Waliczek, & Briers, 2002; Rundgren, 2011; Qin & Brown, 2007, 2008). Among them are gender, level of education, self-perceived interest, religious affiliations, cultural factors such as policy conflicts, and differences in public opinions, risk perceptions and social trust were examined and reported as influencing participants' opinions. The common finding of aforementioned studies is that since participants' knowledge as well as their attitudes tended to be influenced by one or more of these factors, it is necessary to examine and interpret participants' attitudes towards issues in genetics literacy through the lenses of these factors. While Brossard and his colleagues (2008) argue that participants' knowledge and attitudes should be interpreted through the lenses of religious beliefs, Finucane and Holup (2005) indicated that participants' attitudes towards specific applications of genetics like genetically modified food were mainly influenced by cultural factors including policy conflicts, difference in public opinions, risk perceptions and public trust.

The studies summarized in this section provide some direction for this study by providing crucial insight into the factors that might influence PSTs genetics literacy levels as well as their attitudes towards different issues in genetics literacy. In fact, for equipping students with the necessary knowledge and skills in order to be genetically literate, which modern societies strongly need (Bingle & Gaskel, 1994), science teachers themselves should be genetically literate. The need of teachers being informed about advances in genetics research along with the ethical and controversial dilemmas was also emphasized by Kampourakis et al. (2014). Since teachers' own pedagogical beliefs influence development of students' decision making skills as well as concept learning in genetics, it is needed to reveal science teachers' genetics literacy levels and their attitudes towards different issues in genetics literacy. Due to the vital role of science teachers in raising genetically literate individuals, science teacher education programs in Turkey need to critically weigh the long-term consequences of having PSTs to be graduated with sufficient level of genetics literacy as well as holding positions towards genetics literacy issues considering ethical, legal and social implications of these issues over society.

The possible relationships between teachers' and pre-service teachers' knowledge levels and attitudes towards different issues in genetics literacy have been investigated by researchers in national and international contexts (Ozden et al. 2008; orgo & Ambrožič-Dolinšek 2009, 2010; Usak, Erdogan, Prokop & Ozel, 2009). These studies, however, focused on specific issues such as genetically modified foods or gene therapy issues. For instance, Šorgo and Ambrožič-Dolinšek (2009, 2010) investigated the relationship between both in-service and pre-service teachers' knowledge levels and attitudes towards genetically modified organisms (GMOs) and reported that participants had relatively limited knowledge in GMOs and significant but low correlations between attitudes and knowledge

towards GMOs. In as separate study, Ozden and his colleagues (2008) reported that candidate teachers, though, had inadequate knowledge about biotechnology issues, such as chemical hormone usage which showed less favorable attitudes toward the applications of chemical hormones.

As genetics literacy comprises a wide range of issues that have emerged from technological innovations, the need of investigating diverse issues rather than focusing on single issues in genetics literacy has become emergent. Thus, the present study aimed to investigate pre-service science teachers' genetics literacy levels and their attitudes towards diverse issues covered in genetics literacy and the possible factors that were associated with their genetics literacy levels and their attitudes towards different issues in genetics literacy. Moreover, the reform initiatives in Elementary Science Curriculum that was disseminated starting from the year of 2013, socio scientific issues (SSIs) movement has been placed in within science-technology-society part in recent curriculum (MoNE, 2013). As SSIs focus on controversial and ill-structured problems (Zeidler, Walker, Ackett, & Simmons, 2002), issues in genetics literacy overlap with SSIs.

Thus, determining future science teachers' genetics literacy levels as well as their attitudes towards diverse issues has become more important for successful implementation of these issues in science classes.

Research Questions

This research explored how a set of variables, including pre-service science teachers' gender, GPA, monthly income as an indicator of socioeconomic status, self-perceived knowledge and interest in genetics and self-perceived importance of genetics literacy issues are related to their genetics literacy levels and their attitudes towards different issues in genetics literacy. Research questions include:

1. What are pre-service science teachers' genetics literacy levels?
2. What are pre-service science teachers' attitudes towards different issues in genetics literacy?
3. How well do science teachers' socio-demographic characteristics (gender, GPA, monthly income as an indicator of socioeconomic status, self-perceived knowledge and interest in genetics and self-perceived importance of genetics literacy issues) predict their genetics literacy levels, and their attitudes towards different issues in genetics?

Research Methodology

General Background of Study

As the present research aimed to explore the relationship among variables without any attempt to influence them, the explanatory correlational research design was used (Fraenkel, Wallen, & Hyun, 2011).

Participants

The participants of the current research were 355 junior and senior pre-service science teachers (113 males, 231 females and 11 failed to report) from seven public universities located in Turkey. The mean age of the whole sample was 22.04 (*SD*= 1.30). The mean of participants' grade point average (GPA) was 2.70 over 4.00 (*SD*=0.38). Given the fact that the present study focused on genetics literacy, juniors and seniors were selected purposefully since they completed several courses related to biological sciences, including general biology, human anatomy and physiology, genetics and biotechnology, and evolution. Participants were also chosen on account of their willingness to participate in the study.

Monthly income of participants' families, parents' employment status and educational levels were asked as an indicator of socio-economic status (SES). As participants' reported annual household incomes are considered, their household incomes were found to be lower than average Turkish annual household income (Turkish Statistical Institute, 2010). As far as parents' employment status and educational levels are considered, the majority reported to have unemployed mothers (81%) and employed fathers (82.7%). In terms of educational level, 14.6% of mothers and 3.5% of fathers were reported as illiterate. While the majority of mothers and fathers had an elementary school degree (63.2% and 68.7%, respectively), 14.9% of mothers and 25.1% of fathers had a high school degree. However, less than ten percent (6.4%) of mothers and nearly a quarter (21%) of fathers had graduated from university. Relatively few fathers (1.7%) indicated to have a master or PhD degree.

Data Collection Tools

The present research was carried out via paper and pencil administration of *Genetics Literacy Assessment Inventory* and *The Attitudes towards Issues in Genetics Literacy Scale*. Besides, demographic information related to participants' self-perceived interest, knowledge and importance of genetics, gender, grade point average, socio-economic status, employment status and educational level of parents as well as the source of information about genetics applications were collected.

Genetics Literacy Assessment Inventory (GLAI)

The 31-item Genetics Literacy Assessment Inventory (Bowling et al., 2008b), with one correct answer and four distracters addressing concepts identified as central to genetic literacy, was used to assess pre-service teachers' understanding of genetics literacy. The Inventory was developed for assessing American non-biology major' genetics literacy levels and the items were congregated under six dimensions, namely *nature of genetic material*, *transmission*, *gene expression*, *gene regulation*, *evolution* and *genetics, and society.*

GLAI was translated and adapted into Turkish by the researchers of this study. As Hambleton (2005) indicated when adapting an instrument from one language into another language, basic translation procedures may not provide equivalence between original and translated versions of the test. Instead of basic translation from one language to another language, *test adaptation* considering cultural, psychological and linguistic equivalence in a second language is needed (Hambleton, 2005; 1993). Thus, during the translation process, Turkish cultural context was taken into consideration. During this process, *forward translation* that requires adaptation the test from source language into target language was used (Hambleton, 2005; p.12). Then, the original and adapted versions were compared by English language experts at Middle East Technical University Academic Writing Center. During the adaptation procedure, the items which were not suitable for Turkish culture were replaced with the culturally appropriate ones. For example, two questions in *genetics and society dimension*, reflecting legal regulations in American Genetic Information Non-Discrimination Act were replaced by the ones Turkish legal regulation in Human Rights and Biomedical legislation that was enacted in 2003. Additionally, four items from *Evolution Content Knowledge Test* (Rutledge & Warden, 2000) were added to the inventory. Accordingly, the modified version of GLAI consisted of 36 multiple choice items. After being examined by science and biology experts, GLAI, was pilot tested and subjected to ITEMAN analysis. The poor items which had low discrimination indexes (it2= .02 and it4= .02) were removed from the Inventory. The rest of the items were subjected to confirmatory factor analysis for ensuring hypothesized factor structures. The items which have low loading (it17= .01, it21= .10, it24= .01 and it32= .02) were removed from the Inventory. According to confirmatory factor analyses results, the chi-square test was found to be significant ($\chi^2_{(390)} = 565.22$, $p < .05$). As chi-square test is sensitive to sample size (Jöreskog & Sörbom, 1993; Kline, 2010; Tabacnick & Fidell, 2013; p. 700), relative/normed chi-square (χ^2/df) was suggested for decreasing the impact of sample size on chi-square. χ^2/df value was computed as 1.45 in this study indicating a reasonable fit. Other fit indices (RMSEA= .029, CFI= .96, SRMR= .77, and GFI= .95) suggested a good fit. All items loaded on intended factors. Accordingly, the final form of the GLAI included 30 items, under six dimensions: *nature of genetic material* (8 items), *transmission* (4 items), *gene expression* (4 items), *gene regulation* (4 items), *evolution* (6 items) and *genetics and society* (4 items). The internal consistency index (KR-20) was computed as .70.

Attitudes towards Issues in Genetics Literacy Scale (ATIGLS)

The Attitude towards Genetics Literacy Issues Scale is a self-report instrument that allows examination of a variety of genetics literacy components, including *attitudes towards genetics applications*, *the use of genetic information*, *abortion*, *pre-implementation genetic diagnosis*, *gene therapy* and *gene therapy applications* as somatic gene therapy, germ-line gene therapy and in-utero gene therapy (adapted from British Social Attitude Survey, 2000 and Wellcome Trust Consultive Panel on Gene Therapy, 1999) (see Table 1). The scale is made up of 50 items in a multiple Likert Scale format. While *general attitude* items and *use of genetic information* items are a 5-point Likert-type scale ranging from 1 'strongly disagree' to 5 'strongly agree', items in *abortion* and *Pre-implementation genetic diagnosis* dimensions were scored on a 3-point Likert-type scale with 1 being the 'always right' and 3 being 'never right'. The *gene therapy* statements, however, require a response on a scale from 1 to 4 (1= never allowed and 4= definitely allowed). On the other hand, a five-point Likert scale was used in *gene therapy applications* dimension

where 1 indicates 'definitely allowed' and 4 indicates 'never allowed' and lastly 5 indicates 'it depends/needs more information'.

The scale, after being translated and adapted into Turkish by the researchers of the current study, was examined by a group of experts in the fields of science and science education. All the dimensions were found to have satisfactory reliability values, ranging from .62 to .89 (see Table 1).

Table 1. The dimensions of attitudes towards issues in Genetics Literacy Scale.

Dimension	Number of Item	Likert Scale	Description	*α*	*M*	*SD*
General Attitude	19	5 point	Attitudes towards science, genetics technology and genetics research	.65	3.08	6.56
Use of genetic information	4	5 point	Use of genetic information by an employer or insurance company	.62	3.13	2.26
Abortion	4	3 point	To have legal rights for abortion in case of having a disabled child	.73	2.15	2.34
Pre-Implementation Genetic Diagnosis	4	3 point	Use of pre-implementation genetic diagnosis for the families who have the disease risk in their future children.	.79	1.93	2.43
Gene Therapy	10	4 point	Use of gene therapy (changing genes of individuals) in specific situations such as schizophrenia, or being bald	.83	2.30	6.45
Gene Therapy Applications	9	5 point	Use of somatic gene therapy germ-line gene therapy and in-utero therapy	.89	2.28	8.11

Data Analysis

In this research canonical correlation analysis (CCA) was performed to examine patterns in the relationships between two sets of variables. The first set of variables (SET 1) is considered to be the independent variables as participants' self-perceived interest, knowledge and importance of genetics, gender, grade point average, socioeconomic status, employment status and educational level of parents. The second set of variables (SET 2) is considered to be dependent variables and consisted of participants' genetics literacy levels, their attitudes towards different issues in genetics literacy as a general attitude, use of genetic information, abortion, Pre-implementation Genetic Diagnosis, gene therapy and gene therapy applications (see Table 5).

As the research was interested in examining the nature of the independent relationships between two sets of multiple dependent and independent variables, canonical correlation analysis was preferred over simple regression analysis which was suggested by Tabachnick and Fidell (2013). Before using SPSS CONCORR to perform CCA, assumptions (normality, linearity and multicollinearity) were checked (Tabachnick & Fidell, 2013). For checking normality, skewness and kurtosis values were examined and were found between the ranges of +2 and -2 suggested by Pallant (2007). Pearson's product-moment correlations were calculated to test for the existence of multicollinearity and any correlations exceeding 0.8 were detected implying no violation of the multicollinearity assumption (Tabachnick & Fidell, 2013). Lastly, for examining multivariate outliers, Mahalonobis distance values were compared with critical values and presence of multivariate outliers was not detected (Pallant, 2007; Tabachnick & Fidell, 2013).

Results of Research

Descriptive analysis of self-assessment of genetics literacy, GLAI, and ATIGLS

Pre-service Science Teachers' Self-assessment Regarding Genetics Literacy Background

While more than half of the participants reported that they have "a little" knowledge in genetics (56.7%), less than 3% reported having "a lot" knowledge in genetics. Besides, more than a quarter (35.5%) reported that they are "sufficiently" knowledgeable in genetics. A few (5.2%), on the other hand, rated themselves not knowledgeable in genetics. Besides, more than half (65%) claimed to have "a little" of interest in genetics and 17.5% claimed to have

"a great deal" of interest in genetics, whereas less than 10% rated themselves as not being interested in genetics (6.4%). The majority believed in the importance of teaching genetics literacy issues to students (73%) and indicated that teaching genetics literacy issues is worth the effort and time (89.6%).

Pre-service science teachers' responses to the source of information about genetics applications revealed that their main sources were college education (87.3%), followed by Internet (76.6%), newspapers and magazines (74.1%) and television (72.75%). While nearly half identified their friends (48.6%), relatively small percentages identified their families (31.4%) as a main source of information.

Pre-service Science Teachers' Genetics Literacy Level

As shown in table 2, pre-service science teachers provided correct responses to only about half of the questions found in the Inventory (*M*= 14.94). This finding implies that participants were moderately knowledgeable about concepts comprising *Genetics Literacy* such as DNA and chromosome structure, genetic variation, gene activity, meiosis and Mendelian patterns of inheritance in the transmission of genes and nature of genetic material dimensions compared to gene expression and gene regulation dimensions. PSTs, on the other hand, responded less than half of the questions in gene regulation, evolution, genetics and society, implying that they were unaware of the functions of genes in protein synthesis, the role of multiple genes in human traits, including diseases and genetic variation, as well as current and future application of genetics and genetic technologies (see Table 2).

Table 2. Descriptive statistics of GLAI.

Dimension	No. of item	Mean (M)	Standard deviation (SD)	% of participants with correct answer
Nature of the Genetic Material	8	3.93	1.69	50.37
Transmission of Genes	4	2.11	2.12	52.69
Gene Expression	5	1.49	1.04	29.91
Gene Regulation	4	1.52	1.15	37.68
Evolution	5	4.38	2.27	41.15
Genetics & Society	4	1.52	0.95	37.82
Total	30	14.94	3.86	

When the questions that were answered by most of the PSTs were examined, it was found that the majority of the PSTs correctly answered the questions related to science and scientific method (68%) in genetics and society dimension, morphological similarities and differences in a population as an evidence for evolution (67.2%), biological basis of Mendelian inheritance (63.7%) and meiosis (61.5%) in nature of genetic material dimension. Besides, slightly more than half of the PSTs correctly responded to items related to genetic variation (57.8%), DNA structure (57.2%) and the probability in Mendelian inheritance (53.8%). On the other hand, they were completely unaware of the Turkish Human Right and Biomedical legislation that was put into effect in 2003. A great majority of students could not correctly answer this question (92%). Furthermore, less than a quarter appeared to be knowledgeable about mutations and ethical aspects of genetics and genetic technologies.

Pre-Service Science Teachers' Attitudes towards Issues in Genetics Literacy

Descriptive statistics regarding general attitude towards genetics applications, use of genetic information, abortion, Pre-Implementation Genetic Diagnosis, gene therapy and specific applications of gene therapy with respect to total sample were presented in Table 1. As indicated in the table 1, PSTs' mean scores indicated a wide range of approaches to attitudes towards *Issues in Genetics Literacy*. For instance, while PSTs have shown uncommitted opinions regarding items found in *general attitude* dimension such as benefits of modern genetics, the risk of changing and interfering people's genes, and the utility of genetics research (see Table 3 for the sample items), they indicated their agreement on abortion and use of pre-implementation genetic diagnosis especially in cases like mental disability.

Table 3. The frequency distribution of pre-service science teachers' responses regarding general attitude items.

General attitude items	Percentage				
	SD	D	U	A	SA
Many of the claims about the benefits of modern genetic science are greatly exaggerated	6.7	31.0	37.4	21.2	3.7
Changing a person's genes is too risky, whatever the benefit might	5.2	8.7	33.4	38.4	14.2
It is better to try to cure illness without changing people's genes.	4.1	12.9	28.2	37.1	17.6
That in the end, research into human genes will do more to help us than to harm us	4.3	15.9	36.9	36.0	6.9
We should never interfere with people's genes.	7.5	30.0	36.3	18.4	7.8

Note. SD= strongly disagree; D= disagree; U= undecided; A= agree; SA= strongly agree.

Likewise, PSTs generally remained undecided about the *use of genetic information* by different stakeholders such as insurance companies, employers or other authorities (*M*=3.13). While more than a quarter were unsure whether the genetic information should be used or not used by insurance companies (29.4%), the majority indicated their agreement on that the employer should have a right to use this information in the workplace (64%). Besides, the percentages who agreed on that the employer should have the right to see the genetic test results and who disagreed were (35.7% and 42.2% respectively) close implying that the participants did not have a clear picture about usage of genetic information by different stakeholders.

It was noticed that participants' attitudes towards abortion, pre-implementation genetic diagnosis, gene therapy and gene therapy applications change depending on the seriousness of the medical condition under consideration. For example, they thought that abortion should be legal right for women if the fetus was very likely to be born with a *serious mental disability* and would never be able to live an independent life (72.5%) and be born with *physical disability* (65.5%). More than half of the participants, however disagreed with abortion if the child would be healthy, but never grow taller than eight year olds (54%). In the same way, nearly half of the participants were opposed abortion if the child was very likely to be born with a condition that meant it would live in good health but then would die in its 20s or 30s (45%).

PSTs' opinions about *Pre-Implementation Genetic Diagnosis (PGD)* were explored by providing cases related to serious medical conditions. Whilst a great majority (about 75%) indicated their willingness to use PGD in serious *mental* and *physical disability*, less than half opposed to it in case of having a child, which was very likely to live a good health, but then would die in its 20s or 30s (27.6%), or having a child which would be healthy but never grow taller than an eight year old (33.2%).

Similarly, pre-service science teachers' ideas about *gene therapy* were examined in two parts (see Table 4). In the first part, participants were provided by different cases ranging from baldness to breast cancer and were asked for their agreement about the use of gene therapy in the given condition. For instance, while they believe that gene therapy should be used in cases such as *heart disease*, *breast cancer*, *having schizophrenia* and *making a person's average weight rather than overweight,* they, on the other hand, were against the use of gene therapy for *determining the sex of an unborn baby*, or *making someone more intelligent* and *taller/shorter* or *making someone to have full hair rather than being bald*. In the second part, participants' opinions about specific applications of gene therapy, namely somatic gene therapy, germ-line gene therapy and in-utero gene therapy were explored through the cases related to *heart disease*, *cystic fibrosis* and *baldness*. In the same way, while the participants agreed on the use of specific applications of gene therapy *in heart disease* and *cystic fibrosis* cases, they opposed to these applications in *baldness* case.

Table 4. The frequency distribution of pre-service science teachers' responses regarding gene therapy.

Suppose it was discovered that a person's genes could be changed. Do you think this should be allowed to or not allowed to…	Percentage			
	DA	PA	PNA	DNA
Make a person taller or shorter	15.0	46.6	19.5	18.9
Make a person more intelligent	23.3	34.5	23.3	18.9
Make a person's chance of getting heart disease	42.5	37.5	11.2	8.8
Decrease a person's risk of getting breast cancer	50.6	28.3	13.9	7.2
Make a person average weight, rather than very overweight	33.1	33.7	16.0	17.2
Determine the sex of an unborn baby	16.0	22.8	24.9	36.2
To give someone a full of hair rather than being bald	22.4	34.8	23.9	18.9
To stop someone having schizophrenia	47.5	31.0	12.4	9.1

Note. DA= definitely allowed; PA= probably allowed; PNA=probably not allowed; DNA=definitely not allowed.

Canonical Correlation Analysis of Socio-Demographic Variables, GLAI and ATIGLS

Canonical correlation was performed in order to investigate the relationship between pre-service science teachers' socio-demographic characteristics (self-perceived interest, knowledge and importance of genetics, gender, grade point average, socioeconomic status, employment status) and educational level of parents (SET 1) and their genetics literacy levels and attitudes towards different issues in genetics literacy (SET 2). The first canonical correlation was .41 (17% overlapping variance). The first canonical variate was accounted for the significant relationship between two sets of variables. The subsequent pairs were not accounted because χ^2 tests were not statistically significant (p>.05). Accordingly, the first canonical variate was found to be moderately related. Data on the first canonical variates were provided in Table 5.

Table 5. Correlations, standardized canonical coefficients, canonical correlations, percent of variance and redundancies between SET 1 and SET2 variables and their corresponding canonical variates.

	First canonical variate	
	Correlation	Coefficient
SET 1		
Interest in genetics	.53	.45
Knowledge in genetics	.05	-.02
Importance of genetics	.57	.45
Gender	.67	.51
GPA	.01	-.06
SES	.13	-.17
Mother's employment status	.21	.04
Father's employment status	-.07	.01
Mother's educational level	.33	.15
Father's educational level	.37	.34

	First canonical variate	
	Correlation	**Coefficient**
% of variance	17	
Redundancy	.04	
SET 2		
GLAI	.69	.62
General attitude	.20	.11
Use of genetic information	.36	.26
Abortion	.05	.22
Pre-implementation genetic diagnosis	.24	.24
Gene therapy	.55	.34
Gene therapy applications	.59	.33
% of variance	20	
Redundancy	.03	
Canonical correlation	.41	

With a cutoff correlation of .3 as proposed by Tabachnick and Fidell (2013), the first canonical variate was positively correlated with PSTs' self-perceptions about the importance of teaching genetics literacy issues (.57), their self-perceived interest in genetics literacy issues (.53), gender (.67), mother's educational level (.33) and father's educational level (.37). Among genetics literacy levels and attitudes towards issues in genetics literacy set; GLAI (.69), use of genetic information (.36), gene therapy (.55) and gene therapy applications (.59) were positively correlated with the first canonical variate. This finding implied that pre-service science teachers with well-educated parents, male, and those with high level of interest in genetics literacy issues and believing in the importance of teaching genetics literacy issues were more likely to be knowledgeable in genetics literacy and held favorable attitudes towards the use of genetic information, gene therapy and gene therapy applications. Besides, the percentage of variance values indicated that the first canonical variate pair extracts 17% of the variance from socio-demographic characteristics and 20% of the variables from GLAI and attitudes towards issues in genetics literacy variables. Redundancy values indicated that *PSTs' genetics literacy levels, their attitudes towards the use of genetic information, gene therapy, and gene therapy applications* variate accounts for 4% of the variance in PSTs' socio-demographic characteristics. Likewise, *self-perceived interest* and *self-perceived knowledge in genetics literacy issues*, *gender* and *parents' educational level* variate account for 3.3% of the variance in 'PSTs' genetics literacy levels, their attitudes towards the use of genetic information, gene therapy, and gene therapy applications' variables.

Discussion

The need of teachers being informed about the advances in genetics research along with the ethical and controversial dilemmas was emphasized in numerous studies (e.g., Borgerding et al. 2013; Eggert & Bögeholz, 2010; Kampurakis et al. 2014). Thus, successful implementation of these issues into science classes is possible through raising genetically literate science teachers who have required knowledge regarding genetics as well as acknowledge the controversial and ill-structured dispositions of issues in genetics literacy. In this study, we examined to what extent pre-service science teachers' socio-demographic variables, which are self-perceived interest, knowledge and importance of genetics, gender, academic achievement and socioeconomic status (household income, employment status and educational level of parents) predict their genetics literacy levels and attitudes towards various issues in genetics literacy.

The findings, besides providing information about general tendencies of PSTs' genetics literacy levels and their attitudes towards different issues in genetics literacy, also gave important clues regarding the factors that might influence their genetics literacy levels and attitudes towards various issues in genetics literacy. In particular, being male, having well-educated parents, holding a high level of interest in genetics literacy issues, and believing in the importance of teaching genetics literacy are associated with the higher levels of knowledge in genetics

literacy and favorable attitudes towards the use of genetic information, gene therapy and gene therapy applications. In other words, pre-service science teachers who were males, had well-educated parents, had higher levels of interest and believed in the importance of teaching genetics literacy were more likely to understand concepts comprising genetics literacy and develop positive attitudes towards some dimensions of genetics literacy. On the other hand, PSTs' socio-demographic characteristics were not found to be associated with their general attitudes as well as their attitudes towards abortion and pre-implementation genetic diagnosis. This finding indicated that the effects of socio-demographic characteristics were context-dependent implying participants' attitudes differed regarding the issues in genetics literacy being investigated. For instance, PSTs' socio-demographic characteristics (gender, parents' educational level, self-perceived interest in genetics literacy issues, and self-perceived importance of teaching genetics literacy issues) influenced their attitudes towards the use of genetic information, gene therapy and gene therapy applications in the present study. Indeed, descriptive statistics of this research provided evidence that participants demonstrated a wide range of attitudes towards issues in genetics literacy. In fact, having different attitudes towards different applications of genetic technologies is also a common finding in literature (e.g., Črne-Hladnik, Peklaj, Košmelij, Hladnik, & Javornik, 2009; Dawson, 2007; Prokop, Lešková, Kubiatko, & Diran, 2007; Qin & Brown, 2007, 2008; Rundgren, 2011). Črne-Hladnik and her colleagues (2009) reported that participants' attitudes towards genetically modified plants and genetic modifications in animals were differed. The researchers attributed these findings to participants' concerns about the potential effects of these applications on human health and environment and about the violation of animal rights (Črne-Hladnik et al., 2009). In another study, (Rundgren, 2011), similar findings were reported when focusing on genetically modified foods, organic foods and use of DDT topics. Rundgren (2011) interpreted the difference in participants' attitudes towards different issues in genetics literacy as being more knowledgeable about genetics and biotechnological applications. For example, the participants who were more knowledgeable about organic food were also found to be holding more favorable attitudes towards using and buying organic food. The reasons of holding/developing different attitudes towards different issues in genetics literacy may be related with the context that is being investigated (Dawson, 2007; Rundgren, 2011). For instance, Dawson (2007) reported that while most students approved the use of prenatal genetic testing for genetic disease or cloning of endangered species, they disapproved human cloning. The findings of the present study indeed were in parallel with the literature as PSTs' attitudes were differed depending on the issues/contexts being investigated. For instance, while the participants in this study agreed on the use of gene therapy for the purpose of treatment of breast cancer or heart disease, they opposed the idea of using gene therapy for making someone more intelligent or taller/shorter.

It should be underlined that gender explained the highest variation followed by self-perceived importance and self-perceived interest, which means that gender, and self-perceived importance and interest had a relatively strong impact on PSTs' knowledge in genetics literacy and their attitudes. Based on the extant literature, finding gender difference in favor of males may not seem surprising. In fact, gender difference in attitudes towards various issues in genetics literacy such as genetic engineering, genetically modified foods or genetic modifications in animals have been reported (Črne-Hladnik et al., 2009; Prokop et al., 2007; Qin & Brown, 2007, 2008) and previous studies supported the idea of females having less favorable attitudes towards various issues in genetics literacy. Indeed, our findings are also in parallel with the literature reporting males having more positive attitudes towards some of the issues in genetics literacy (Črne-Haladnik et al., 2009; Prokop et al., 2007). For instance, Prokop et al. (2007) reported that male students had more positive attitudes towards biotechnology issues including genetic engineering practices and GMOs when compared to female counterparts. The researchers explained this as males had better knowledge of biotechnology. Likewise, Črne-Haladnik et al. (2009) indicated that male students have more favorable attitudes towards germ-line gene therapy and that female participants with better genetics background had higher risk perceptions regarding gene therapy, which may cause occurrence of negative attitudes towards gene therapy. As Klop and Severiens (2007) noted, affective evaluations and behavioral intentions do also affect participants' attitudes differently. Thus, explaining the relationship between knowledge and attitudes towards various issues comprising genetics literacy may be more complex as ever. Accordingly, we inferred that the significant difference in male and female PSTs' attitudes might be arise from the concerns they held about risk factors or trust in genetic technologies (Črne-Hladnik et al., 2009; Qin & Brown, 2007). Gender differences, however, continue to merit further study.

The results of the current study provided some evidence that parents' levels of education also played an influential role in explaining the variation in PSTs' genetics literacy levels and attitudes towards various issues in genetics literacy. This outcome, in fact, is not surprising; PSTs who have educated parents were more likely to have

more opportunities to develop interest in genetics literacy issues and have more favorable attitudes towards issues in genetics literacy, such as accessing resources like Internet or having personal computer for accessing information regarding genetic technologies or being more aware of genetics technologies. Thus, it can be expected that having educated parents who are aware of genetics literacy issues will be resulted in creating facilities for their children to be more aware of issues regarding genetics literacy as well as to develop more favorable attitudes towards issues in genetics literacy. Several studies in the existing literature also have provided ample evidence for the relationship between education level and scientific enterprise (Dauber & Epstein, 1989; George & Kaplan, 1998) as well as with achievement in science (Desimone, 1999; Jabor et al. 2011). The mediating role of parental (especially maternal) level of education on students' achievements, educational outcomes and expectancy beliefs (Desimone, 1999; Feinstein & Sabates, 2006; Jabor et al. 2011; Okpala, Okpala, & Smith, 2001; Sacker, Schoon, & Bartley, 2002; Rhea & Otto, 2001) were also reported. For instance, Feinstein and Sabates (2006) found that more educated mothers tended to have more favorable attitudes towards the issues regarding their children's attitudes. Overall, they indicated that well educated parents were more involved in their children's education and thus, parents' education level influenced students' attitudes towards science and facilitates students' learning in science.

To conclude, the present research presented a general overview of Turkish PSTs' attitudes towards different issues in genetics as well as their genetics literacy levels and their relation to socio-demographic characteristics. A number of socio-demographic characteristics including gender, education level of parents, self-perceived interest in genetics and self-perceived importance of genetics literacy were found to be associated with PSTs' genetics literacy levels and their attitudes towards different issues in genetics literacy. Moreover, PSTs' socio-demographic characteristics were only found to be associated with some issues in genetics literacy, including gene therapy and gene therapy applications, implying that participants' attitudes differed regarding issues in genetics literacy being investigated. As PSTs are future teachers who will be critically important in raising future's scientifically as well as genetically literate individuals, this study reveals important issues. Teacher education programs in Turkey need to address genetics literacy in their curriculum in order to graduate pre-service science teachers as genetically literate and be aware of the issues in genetics literacy. To this end, science teacher educators need to include genetics literacy issues into their courses and notice the importance of teaching and understanding of genetics literacy issues as well as other concepts in science.

Implications and Directions for Future Research

The present study has some limitations that may have implications for further studies. First, the present research was based on a small sample of pre-service science teachers in seven public universities which may not represent genetics literacy levels and attitudes of all Turkish PSTs. Although the results of the current study provided us with some valuable clues about Turkish PSTs' genetics literacy levels, their attitudes towards genetics literacy issues and the possible relationships among socio-demographic characteristics, PSTs' genetics literacy levels and their attitudes towards different issues in genetics literacy; it would be useful to conduct a nation-wide study with a larger number of participants.

Second, only self-report instruments that have a limited number of items were utilized in the present study. Thus, the items in GLAI and ATIGLS may not sufficiently assess genetics literacy level of PSTs and their attitudes towards various issues in genetics literacy. Subsequent studies are needed to verify the accuracy of the present findings through the use of qualitative and mixed methods. As this study was exploratory in nature, further studies employing experimental methods and various qualitative methods such as interviews and observations would be helpful. Even though this study had some limitations; the results have practical implications for pre-service science teacher education programs. Therefore, this study will serve as a basis for further research in national context.

As previous national and international studies usually focused on one or two aspects of genetics literacy (for instance, genetically modified food or gene therapy), this study emphasized the importance of including multiple issues in genetics literacy and indicate some directions for possible research areas about inclusion of multiple issues while investigating these issues as well as the relationships among them.

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