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ORIGINAL

Genetic Determinism and Essentialism in the Student's Minds: A Qualitative Exploration of Perceptions

Determinismo genético y esencialismo en la mente de los estudiantes: una exploración cualitativa de las percepciones

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ABSTRACT

Introduction: genetic determinism and essentialism are scientifically rejected beliefs that may propagate inequity in several aspects of life.
Objective: this study aims to systematically explore the narrative constructs of students' genetic determinism and genetic essentialism concerning biological attributes, social standing, and career advancement; explore the impact of students' beliefs in genetic determinism and essentialism on their perceptions of social discrimination and current policy; and explore students' understanding of genomic variety as a potential way to mitigate prejudice caused by genetic determinism and genetic essentialism.
Method: narrative data were collected from 408 students in Indonesia using an open-ended questionnaire and subsequently analyzed using theme analysis.
Results: the study's findings indicate that students frequently use a determinism and essentialism framework to explain variations in traits, social position, and professions, often ignoring the complex nature of gene-environment interactions and resulting in racial behaviours. The narrative is intimately associated with issues of discrimination in employment, education, and healthcare sectors. While students generally acknowledge the concept of genomic variety, which may reduce beliefs in genetic determinism and essentialism, concrete efforts are still required to enhance its significance.
Conclusions: this study concludes that a persistent and incorrect understanding of genetics is present among students, requiring the reinforcement of the concept of genomic variation as a basis for enhancing genomics literacy in genetics education, which can ultimately mitigate stigma and social inequality.

Keywords: Narrative; Genetic Determinism; Genetic Essentialism; Genomic Variation.

RESUMEN

Introducción: el determinismo y el esencialismo genéticos son concepciones científicamente refutadas que tienen el potencial de propagar la desigualdad en diversas facetas de la existencia.
Objetivo: este estudio tiene como objetivo examinar de manera sistemática los constructos narrativos del determinismo y el esencialismo genéticos de los estudiantes en relación con los atributos biológicos, la posición social y el desarrollo profesional; analizar el impacto de sus creencias en el determinismo y el esencialismo genéticos en sus percepciones de la discriminación social y las políticas actuales; y evaluar su comprensión de la diversidad genómica como una posible estrategia para mitigar los prejuicios derivados del determinismo y el esencialismo genéticos.
Método: se recopilaron datos narrativos de 408 estudiantes en Indonesia mediante un cuestionario abierto y se analizaron posteriormente mediante análisis temático.

Resultados: los hallazgos del estudio indican que los estudiantes utilizan con frecuencia un marco de determinismo y esencialismo para explicar las variaciones en los rasgos, la posición social y las profesiones, ignorando a menudo la naturaleza compleja de las interacciones entre genes y ambiente, lo que resulta en comportamientos raciales. Esta narrativa está estrechamente relacionada con problemas de discriminación en los sectores laboral, educativo y sanitario. Si bien los estudiantes generalmente reconocen el concepto de variedad genómica, lo que puede reducir las creencias en el determinismo y el esencialismo genéticos, aún se requieren esfuerzos concretos para fortalecer su importancia.
Conclusiones: este estudio concluye que existe una comprensión persistente e incorrecta de la genética entre los estudiantes, lo que requiere reforzar el concepto de variación genómica como base para mejorar la alfabetización genómica en la educación genética, lo que en última instancia puede mitigar el estigma y la desigualdad social.

Palabras clave: Narrativa; Determinismo Genético; Esencialismo Genético; Variación Genómica.

INTRODUCTION

Genetic determinism is the belief that genes invariably determine phenotypes, resulting in almost no effects from environmental changes on the individual's traits.[1,2,3] Over the past two decades, genetic research has clearly and definitively rejected the beliefs of genetic determinism. Nevertheless, public acceptance of genetic determinism remains at an enormous level. A community-based survey involving 717 participants, including African American and Caucasian American respondents, revealed that beliefs in genetic determinism have been classified into two related domains: perceived genetic threat (e.g., susceptibility and severity of disease) and biological essentialism (e.g., the immutable role of genes in health outcomes).[4] A study with two independent samples (N = 301 and N = 740) examined public perceptions regarding free will, determinism, and the genetic/environmental basis of 21 human traits. The results indicated that laypersons' judgments of genetic influence comprised four separate clusters, correlated with individual beliefs in human authority, religion, and political orientation. The correlation between lay estimations and published heritability estimates for the studied traits is high (r = 0,77).[5]

This explanation of genetic determinism provides a strong basis for the role of genes in determining individual traits, although the fact that many traits are influenced by genetic variables in a simplistic or minimal way. This belief in genetic determinism includes claims that increase the impact of hereditary traits.[6] Variations in certain socially important traits or behaviours, based on the belief in genetic determinism, are primarily controlled by individual genetic and social factors rather than nongenetic environmental factors.[2] The focus on genetic determinism consists of five components: 1) restricting the range of potential causal factors affecting a specific trait (phenotype), 2) overestimating the causal significance of an individual gene (or a group of genes) in determining a trait, 3) ignoring other nongenetic (often non-DNA) factors that may influence the development of a trait, 4) separating genetic causal factors from the impacts of other cellular, extracellular, and extra-organismal influences on genes, and 5) emphasizing the unique contributions of genes or the specificity of genetic effects in contrast to the roles and impacts of nongenetic factors.[7]

This perspective on genetic determinism was later stated as a variant of naturalism, where qualities with a strong genetic foundation serve as a natural rationale for each human.[1,8] This belief in genetic determinism may facilitate the rise of eugenics in society, an idea created by geneticist Francis Galton, which refers to the idea that selective breeding can enhance human quality. Eugenics had profound effects on minority communities in the United States and other nations during the 19th and 20th centuries.[9] Moreover, the numerous fallacies of genetic determinism can act as a foundation for the development of racial ideologies, such as genetic essentialism.

Genetic essentialism is a racist belief system that attributes moralized to characteristics and implies the existence of a homogeneous group separate from others. Genetic essentialism claims that genes provide the unique "essence" of humanity,[2] which may serve as a basis for prejudice and the justification of inequalities of race.[10] Race is considered an immutable characteristic of a homogeneous group. This essentialist claim states that individuals believed to come from a homogeneous group cannot possibly develop from distinct gametes.[11] Individual identity is regarded as a manifestation of the group's consistent and important genetic characteristics while it remains fundamentally distinct from other groups.[12] According to this perspective on genetic essentialism, beliefs on the association between community groups or races and genetics are significant and incontrovertible.[13] This conception will adversely affect intergroup sentiments, support for social policies, and systems of inequality.

The interplay between genetic essentialism and genetic determinism in social discourse likely leads to conceptual and cognitive problems. Various expressions of these cognitive mistakes will ultimately support

inequality across numerous social domains. One category pertains to those with mental disorders.[14] Beliefs in genetic determinism and genetic essentialism frequently foster isolation from society in patients[15] and induce fear from the surrounding environment, undermining the value of anti-stigma campaigns and inhibiting effective medical decision-making.[16] Moreover, beliefs in genetic determinism and genetic essentialism may foster sexism and ableism, so propagating stereotypes and legitimizing discriminatory practices.[17] In education, these two perspectives contribute to the decreasing individual motivation for personal development through learning processes or environmental interventions.[18] Psychologically, belief in genetic essentialism and genetic determinism can reduce individual responsibility and self-assurance through life changes, consequently impacting motivation and behaviour in educational environments.[19] In order to mitigate these diverse consequences, one must possess a critical comprehension of the deterministic and essentialist narratives that are increasingly prevalent in society.

However, at present, few studies investigate the narratives of genetic determinism and genetic essentialism across many aspects of life, including biological traits, social status, and professional fields within society. Numerous studies concerning genetic determinism and essentialism have predominantly focused on definitions and misconceptions,[1,8,20] current perspectives,[20,21,22] challenges and critiques,[23] and future research and education recommendations.[24] This research prioritizes quantifying beliefs in genetic determinism and genetic essentialism, as well as detecting their relationships, rather than conducting an in-depth examination of the narratives around these two views. Numerous prior studies have indicated that to comprehensively understand the development of beliefs in genetic determinism and genetic essentialism among individuals or societal groups, exploratory research is required to examine fundamental aspects of respondents, including cultural impacts,[25] religiosity,[26] social factors,[15] and education.[10] The absence of narrative studies concerning the investigation of genetic determinism and genetic essentialism beliefs leads to several problems due to insufficient information regarding 1) diverse contextual insights, 2) examinations of personal and social contexts, 3) diminished epistemological and methodological diversity, 4) inadequate representation of human experience, 5) absence of a holistic understanding, 6) compromised capacity to navigate complex phenomena, and 7) obstacles to knowledge synthesis. To contribute to a more comprehensive study, this study will explore the narrative representations of genetic determinism and genetic essentialism in students across various domains, including biological traits, social status, and emerging professions.

After a comprehensive analysis of genetic determinism and genetic essentialism narratives, a further study can be conducted to explore the influence of these ideas on social discrimination problems and relevant policies. Theoretically, the development of negative views in people or groups significantly increases the probability of inequality manifesting as social discrimination[17,26,27] and discriminatory laws.[28,29] Through the reporting of this research investigation study, it is possible to determine further the extent to which genetic determinism and genetic essentialism beliefs influence concerns regarding social discrimination and relevant policies. Implicatively, this study will also explore how the concept of genetic variation can play a role in reducing the level of racism within a societal group.

Objective

The research was conducted to:

1. Explore the narrative constructs of students' genetic determinism and genetic essentialism concerning biological attributes, social standing, and career advancement.
2. Explore the impact of students' beliefs in genetic determinism and essentialism on their perceptions of social discrimination and current policy.
3. Explore students' understanding of genomic variety as a potential way to mitigate prejudice caused by genetic determinism and genetic essentialism.

METHOD

Study Context and Participants

This exploratory study is designed to comprehend students' perspectives on genetic determinism and genetic essentialism through an open-ended questionnaire. This study applied a purposive sampling technique, selecting respondents who were university students in Malang, Indonesia, participating in a Genetics course. Most students who participated in this study had acquired fundamental knowledge of genetics during their secondary school years or general biology lectures.

The data collection for this study was conducted through four open-ended questions presented as assignments. The deadline for completing the questionnaire was one week before the genetics lecture. Respondents were given the opportunity to collaborate with 2-3 group members while completing the assignment. After completing the work, respondents returned this questionnaire to the study team during the genetics lecture events. This survey was conducted in May 2024, involving 408 students, comprising 85 percent female and 15 percent male participants. Participants were recruited for an exploratory data collection on ideas regarding genetic

determinism and genetic essentialism by contacting all students enrolled in the fourth-semester genetics course at the Faculty of Mathematics and Natural Sciences, Department of Biology.

Assessing Genetic Determinism and Genetic Essentialism Holistically

After evaluating several available instruments, none were entirely suitable for our needs, either due to an excessively broad or limited scope or because they required data analysis exceeding our team's capabilities. Consequently, developing our questionnaire by modifying a previous one or constructing a new instrument for a more comprehensive evaluation would be more suitable. This new instrument was designed to include questions specifically aimed at assessing the beliefs of our study population concerning genetic determinism and genetic essentialism. The questions employed in this instrument were:

1. Recombination is a major mechanism influencing genomic variety, relating not only to the arrangement of genetic diversity but also to the repair of damaging mutations within a population. How does the concept of recombination contribute to mitigating racism within a group of individuals?
2. After the success of Jamaican sprinters at the 2012 Olympics, several individuals claimed that the team's physical prowess is attributable to their ancestors' status as slaves. The claim states that slaves needed considerable power and stamina to face physical challenges for survival, which led to the prevalence of specific physical attributes, such as enhanced muscle mass, an efficient respiratory system, and rapid muscle response—traits advantageous to the explosive speed required by sprinters—among their descendants, thereby providing these descendants superior sprinters compared to other ethnic groups.[30]
3. In the late nineteenth century, Francis Galton conducted comprehensive research demonstrating that important professions—such as lawyers, judges, doctors, members of Parliament, and artists—often persisted within familial lineages. Galton explained this by asserting that the cognitive attributes necessary for success in certain professions—such as intelligence, creativity, or self-motivation—are biologically inherited. 2012 study in the UK states the identification of specific genetic markers in families with numerous members assuming top roles in business and politics.[30]
4. As genetic testing and genome sequencing increase frequency, how can we avoid developing "genetic discrimination" in employment and healthcare contexts?

Data Analysis

This study applied thematic analysis for data analysis facilitated by NVivo software. Thematic analysis, as a qualitative data analysis technique, facilitates a thorough examination of descriptive data, resulting in developing a conceptual model and synthesizing the researcher's findings. The thematic analysis method consists of six primary stages: (1) transcription, data familiarization, and quotation selection; (2) keyword selection; (3) coding; (4) theme development; (5) conceptualization by interpretation of keywords, codes, and themes; and (6) development of a conceptual model.[31] The presence of this systematic procedural framework can enhance accuracy and mitigate the risk of interpretative bias in qualitative research.

In the first processes, namely transcription and data familiarization, the researcher undertakes an in-depth content investigation to discover beginning themes and essential elements of the research data. Moreover, the researcher identifies relevant quotations that effectively illustrate diverse viewpoints and trends associated with the research focus. In the second stage, keyword selection, the researcher undertakes a comprehensive data analysis to uncover frequent trends or terms, subsequently designating them as keywords. These keywords reflect the experiences and perceptions of respondents obtained directly from the data narrative.

The initial screening findings indicated that data were collected from 91 % of respondents who provided complete answers to all four questionnaire items. Simultaneously, approximately 9 % of other respondents submitted incomplete responses, making the data inappropriate for subsequent analysis. All data that passed this preliminary evaluation were subsequently input into NVivo software for thematic analysis. The initial study involved a narrative evaluation of the research data utilizing the Word Frequency Query tool. This feature provides information on the frequency of engaging and interesting words based on respondent data.

In the third phase, coding, researchers designate phrases or brief terms as codes containing the data's fundamental meaning, importance, or theme. This coding technique focuses on clarifying complicated textual material by converting it into a theoretical framework, simplifying the identification of aspects important to the study problem. Keywords are crucial in this phase as they constitute the foundation of the analysis, facilitating the organization of raw data into coherent units that can subsequently be converted into codes. The majority of the codes in this study are inductive. The research team cross-verifies to ensure consistency among the generated codes. Any identified discrepancies or newly formed codes are collaboratively discussed, subsequently evaluated, and modified through a re-coding process informed by the data's context. The fourth step, theme development, is categorizing codes into coherent groupings to identify patterns and correlations which provide insights into the research question. At this point, researchers transition from detailed evaluation

of codes and categories to more abstract interpretations through the development of themes. The themes signify meaningful patterns linking the data to the study's topic. At this step, the research team engaged in repetitive discussions to consolidate coherent themes across authors and discover patterns indicating internal and external uniformity across all codes. In the fifth stage, conceptualization, the research team analyzed and defined the concepts generated by the data by recognizing relevant social patterns and organizing them into concepts compatible with the study framework. This approach involves further interpretation by visualization through diagrams or models that represent the interconnections among concepts comprehensively.

The culminating phase of thematic analysis involves the development of a conceptual model, which includes creating a distinctive and significant representation of the data, frequently by referring to established ideas. At this point, the research team collaborated to formulate concepts and identify linkages among concepts and literature to solve research questions while validating the value of findings to advance knowledge. This stage represents the end product of the entire analytical process, as it cohesively synthesizes the principal results and conceptual insights derived from the data.

Ethic aspects

Students reporting interest received a consent form detailing the study's goal and expected participation. After that, the team obtained informed consent from all involved students. Furthermore, every aspect of this study received evaluation and approval from the Ethics Committee of the State University of Malang with the number No.17.10.2/UN32.14.2.8/LT/2024.

RESULTS

Narrative Framework of Genetic Determinism and Genetic Essentialism Among Students

The search results compiled the most often seen words in the data, as illustrated in figure 1. The primary word identified was "genetic" followed by various other phrases, including "factor", "discrimination", "recombination", "gene", "individual", "racism", "society", "intelligence", "ability", "education", and many additional words in varying frequencies. This compilation of terms clearly shows the correlation between students' narrative tendencies and their beliefs in genetic determinism and genetic essentialism.

Figure 1. Most Frequently Appearing Words from Data in Indonesian

The Impact of Students' Beliefs in Genetic Determinism and Genetic Essentialism on Social Discrimination and Policy

When the formation of genetic determinism and genetic essentialism ideas in students is exposed, it is crucial to conduct additional research into how these two beliefs affect numerous elements of life, including social and policy issues. A more thorough comprehension of this influence can be elucidated by project mapping, which is represented as a hierarchy diagram. A hierarchy diagram is a visual representation consisting of layered rectangles that illustrate each node's coding proportion or intensity according to the visible area. Figure 2 is a hierarchy diagram illustrating the impact of genetic determinism and genetic essentialism views inside the social domain. According to the findings presented in figure 2, the development of views on genetic determinism and genetic essentialism among students might influence multiple sectors of the social domain, particularly in "employment," "education," and "health."

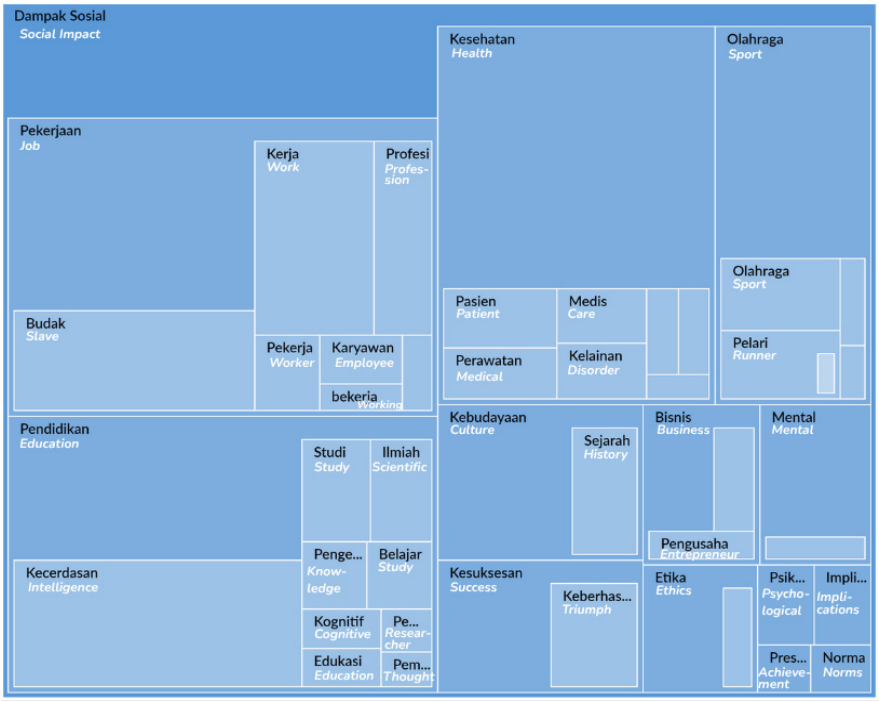

Figure 2. Hierarchical Diagram Illustrating the Impact of Genetic Determinism and Genetic Essentialism Beliefs on Social Discrimination (Modified with the addition of English)

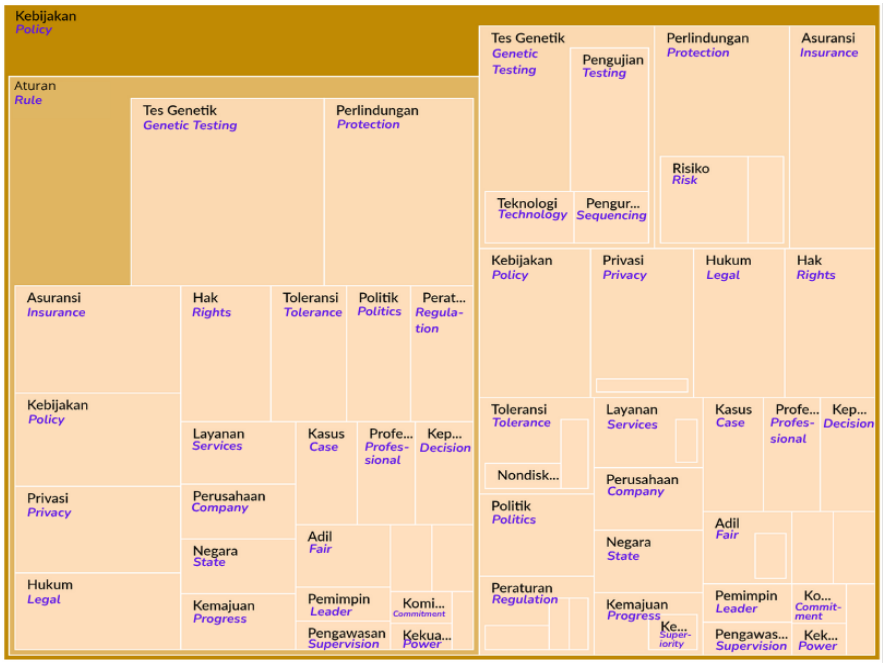

Figure 3. Hierarchical Diagram Illustrating the Impact of Students' Beliefs in Genetic Determinism and Genetic Essentialism on Policy (Modified with the addition of English)

Beliefs in genetic determinism and genetic essentialism can significantly affect students' policy viewpoints, as illustrated in figure 3. According to the data presented in figure 3, the domain of genetic testing and genetic data protection is particularly emphasized by several students. Alongside several components, including insurance, privacy, law, state, and services, it may clearly illustrate students' viewpoints on the impact of genetic determinism and genetic essentialism within the policy domain.

Efforts to Mitigate Racism resulting from Genetic Determinism and Genetic Essentialism Through the Interpretation of Genome Variation

Beliefs in genetic determinism and essentialism have demonstrated harmful effects, particularly in maintaining racial prejudices at both individual and societal levels. To solve this problem, a viable strategy is to offer a thorough comprehension of genomic variation. The concept of genomic variety has the ability to mitigate multiple aspects of racist perspectives, as illustrated in figure 4. The network structure shown in figure 4 illustrates that the concept of genome variation, covering biological, phenotypic, physical, environmental, and other dimensions of diversity, extends a simple biological domain and may serve as a crucial framework for mitigating disagreements related to genetic determinism and essentialism.

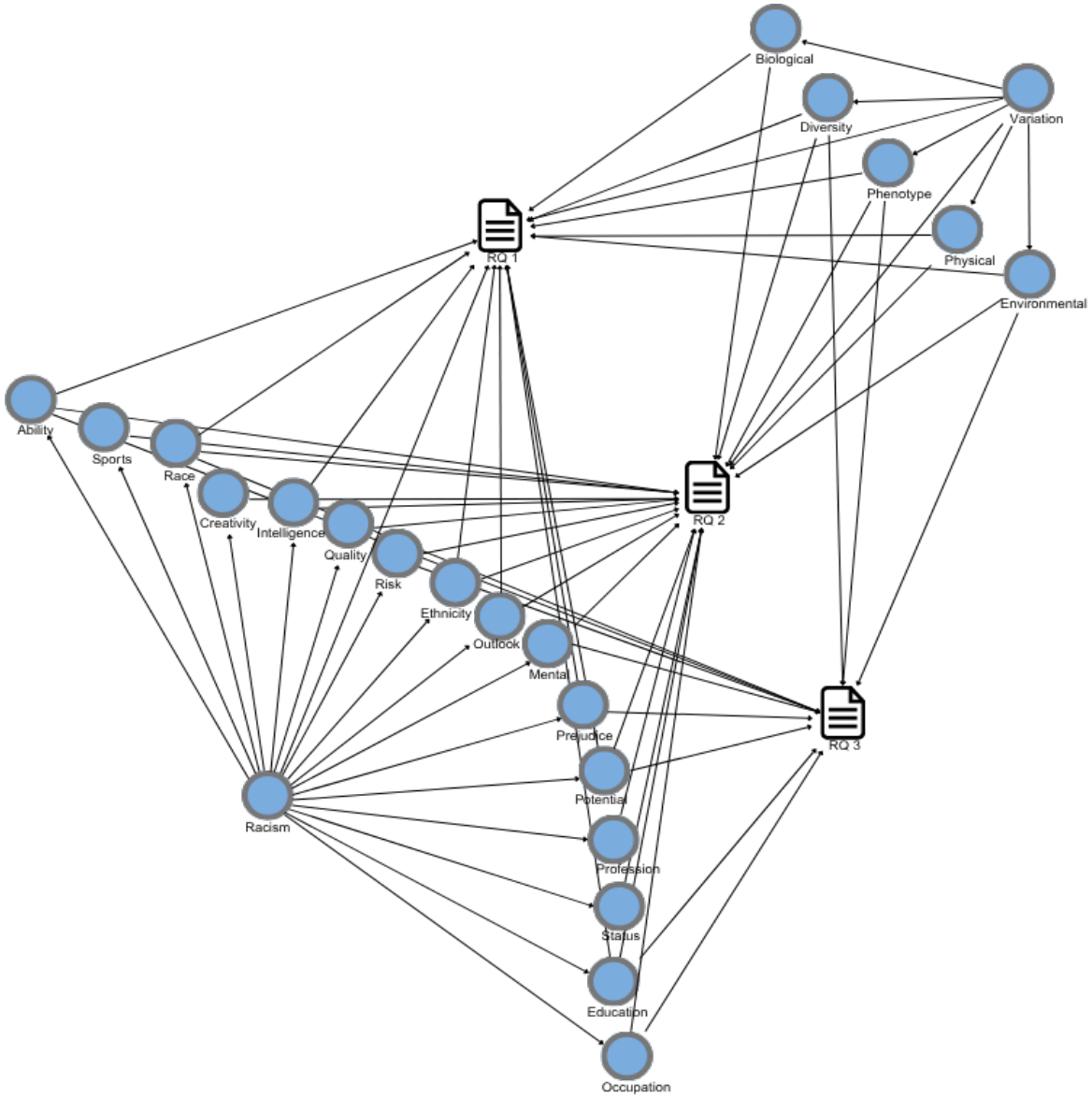

Figure 4. Interaction Pattern of Genome Variation Concept with Racist Views (Modification in English)

DISCUSSION

Narrative Framework of Genetic Determinism and Genetic Essentialism Among Students

In this discourse, the first use of the primary word, specifically "genetic", serves as a key concept that integrates the narratives of genetic determinism and genetic essentialism. The word genetic presently includes

more than just biological information or DNA structure; together with the word "gene", it has been used to explain and even rationalize disparities in qualities, societal status, and potential based on biological factors. The term "factor " further reinforces this tendency, indicating that genes act as the primary determinants of trait development despite environmental impacts or life experiences. Moreover, the use of the term "individual" in the narrative implies a belief that a person is an entity that includes a set of immutable hereditary variables that significantly impact essential traits throughout their lives. These narratives typically illustrate the development of beliefs in genetic determinism that meet with various prior conceptions. In some conceptions that have developed, genes are understood as the primary cause in the formation of human traits at the individual level; furthermore, genes are believed to have greater causal power than scientific explanations in determining a trait.[7,8,32,33] In a more powerful perspective on belief, genetic determinism is regarded as a mechanism of phenotype formation solely "determined by natural law" and dependent on the individual's genotype composition, disregarding the influence of personal choices, behaviours, or environmental factors.[1,2,26] Implicitly, this determinism belief perspective leads to the assumption that pathological conditions influenced by "genetics" can only be resolved through interventions to the individual's genome.[14,34,35] This claim can imply that changes in specific genes have a deterministic effect on the development of traits in individuals who experience these changes without considering the complexities of gene-environment interactions.[7]

The concept that genes biologically determine phenotypes is indeed accurate; however, the implications of this perspective must be reviewed to ensure that they are consistent with empirical evidence. Genes, as functional units of DNA that facilitate RNA production, causally contribute to the development of phenotypes. Nonetheless, the general perception of the function of these genes is frequently oversimplified, specifically that genes determine human traits.[1] This common misconception is further fostered by media and textbooks that poorly represent the intricacies of biological systems examined by several fields of study.[26,36] Based on an epistemological perspective, phenotypes cannot be seen as static or simply the outcome of genetic expression. Phenotypes are produced by a complicated interaction between genotype and environment during the individual's developmental way. The separate view of hereditary and environmental influences, which is still common, overlooks their co-constitutive interaction. This type of deterministic view has been widely criticized by scientists from a variety of fields, including developmental biology,[37,38] evolutionary biology,[39,40] physiology,[41] molecular genetics,[42] philosophy of biology,[12], psychology and behavioural neuroscience,[43] and behavioural genetics.[8,44] All these theoretical contributions indicate that genes, within a conceptual framework, cannot be perceived as independent causal entities; instead, they are components of a relational system interconnected with individuals' environmental, historical, and experiential contexts.

In the essentialist view, the word "genetic", which relates to "gene", can be taken as a fixed and unchanging substance that is bound to a group, whether race, ethnicity, or gender, and is then used to distinguish between "us" and "them". This interpretation suggests that genes make up an individual's primary source or "essence", implying that genetic factors entirely dictate personal traits, are immutable, and serve as the principal rationale for an individual's beliefs and actions.[20,45,46] This perspective of genetic essentialism argues that individuals within a group have inherent and immutable attributes that shape their traits, behaviours, or talents.[13] Essentialist concepts propose that human groupings contain biological, cognitive, and cultural attributes that are homogeneous across members and transmitted between generations within the group.[47] This essentialist perspective is frequently linked to the belief that group membership is exclusive, meaning that membership to one group prevents connection with another and that the group is considered a cohesive unit.[13]

This study's findings concretely illustrate the concept of genetic essentialism through the term "society", frequently used by students to provide certain traits—be they inherent, behavioural, or capacity-related—that are permanently linked to social groups and biologically inherited. This narrative illustrates that students continue promoting a social perspective that attributes individual variations to a basic biological basis, consistent with the principles of genetic essentialism. Moreover, other data indicate that essentialist beliefs come not alone from limited biological understanding but are also shaped by wide social constructs and continue in daily cognition.[1,45,48] Numerous studies indicate that simplified presentations of genetic explanations might reinforce essentialist beliefs, particularly when genetic knowledge is separated from the complexities of development and environmental context.[12,26,45,49,50]

This essentialist viewpoint becomes even more apparent when students represent genes, genomes, or DNA as immutable essences that determine human characteristics, including intelligence, academic success, behaviour, and illness susceptibility. In this framework, genes, genomes, and DNA are considered systems of an individual's internal essence, which is considered immutable, innate, and hereditary.[1,3,8] The belief in genetic essentialism among students can be seen in the emergence of narratives such as "discrimination", "racism", "education", "intelligence", and "ability" indicating the tendency to associate genetic identity with immutable social characteristics. This research indicates that students replicate the biologization narrative of social traits and promote the belief that social inequalities are manifestations of immutable biological factors. One illustrative student statement from the survey reads:

"Genetic factors can be inherited from the mother. This is attributable to genetic influences by the maternal mitochondria"

This claim reflects the persistence of essentialist reasoning in students' understanding of genetics, particularly in conflating biological inheritance with socially constructed traits.

The findings indicate that concerns about the increasing application of genetic reasons to justify social discrimination are becoming more visible in the development of beliefs in genetic essentialism. Genetic essentialism manifests as a misunderstanding of biological concepts. It provides a cognitive framework that justifies social inequalities, including racial hierarchy, by presuming that specific groups contain better or inferior genetic characteristics.[1] These beliefs increase the legitimacy of inequality, rendering privileges for specific groups become natural and permitted.[13,23] As hierarchical views of the hereditary traits attributed to people or groups are considered, access to health care, education, and other life changes becomes more structured.

When this belief continues without careful evaluation, various forms of discrimination become challenging to identify and more legitimized through specific scientific terminology or symbols. In this study, concepts like "recombination" were not completely comprehended to decrease this essentialist viewpoint on thinking. The development of multiple scientific narratives in this study is still insufficient to change students' fundamental assumptions that individual identity and capacity cannot be reduced to fixed genetic categories. This interpretation suggests that the scientific framework often reduces human complexity to fixed and absolute biological traits.[10,13,27] This finding also confirms that the inaccurate application of genetics as a foundation for social significance is not only conceptually dangerous but also carries significant ethical consequences for the normalization of increasing hidden and systemic discrimination.

The Impact of Students' Beliefs in Genetic Determinism and Genetic Essentialism on Social Discrimination and Policy

Beliefs in genetic determinism and genetic essentialism can have an impact on various social domains, especially "employment", "education", and "health" (figure 2). The rise of genetic-based conceptions in the employment sector might foster severe discriminatory attitudes, including social labelling that may result in the concept of slavery, alongside limitations on specific professions based on genetic capacity. Prior research has indicated that genetic discrimination is recognized and manifests within the employment sector in various areas,[29,51,52] including Canada.[53] In Canada, individuals with a known genetic predisposition to specific diseases may be excluded from the recruiting process despite the absence of any symptoms. Furthermore, while not directly related to recruitment, the challenges associated with acquiring life insurance based on genetic test outcomes might influence a person's career status, particularly in sectors which require personal insurance coverage as a prerequisite for employment. Specifically, it is noted that Canada lacks a national statute that explicitly forbids using genetic information in job determinations. Consequently, employees or job applicants lack strong legal safeguards against discrimination based on genetic information. Discrimination in employment and workplace interactions for those predisposed to hereditary diseases, such as Huntington's Disease, is prevalent in various sectors.[54,55] Genetic discrimination in employment can include diminished performance evaluations, lack of promotions, and unfavourable treatment based on genetic knowledge.[51,56,57] Many companies lack authentic dedication to fostering an ethnically diverse staff, particularly inside the highest positions. This discrimination is frequently nuanced yet intricate, complicating efforts to confront and reduce it.

In education, the impact of genetic determinism and genetic essentialism can be seen in narratives that associate intelligence, academic achievement, and cognitive ability with certain group classifications in the learning process. The following excerpts, drawn directly from student responses in this study, demonstrate the belief that cognitive traits such as intelligence are significantly influenced by genetic inheritance and are seen as determinants of personal capacity and social mobility. Students stated:

"Parents' intelligence and creativity can be inherited by their offspring. Regardless of whether children are nurtured by their biological parents or others, the inherent intelligence of the parents will be transmitted, thereby reflecting the children's intellectual capacity".

"I concur with the assertion that mental attributes, including intelligence, creativity, and motivation, are biologically inherited from parents to offspring. (...) Consequently, it is unsurprising that families possessing advantageous mental quality genes hold top roles in industry and politics".

These statements reflect how essentialist genetic thinking continues to shape students' assumptions about education, ability, and social stratification.

This exclusivity in learning may consequently promote intolerant views, such as racism, and increase cognitive biases among students.[32] Students classified within the high intelligence group will encounter higher standards for achievement and improved support, facilitating the growth of optimistic attitudes regarding academic ability, which subsequently can enhance achievement and self-concept.[58,59] Students in other groups tend to exhibit more pessimism and receive diminished help in obtaining academic achievement. Implicationally,

teachers' beliefs of genetic impacts on students' skills can influence their expectations and instructional approaches.[60] For instance, teachers who believe that intelligence and learning difficulties are significantly affected by genetics may modify their instructional approaches based on the genetic profiles of students to optimise learning outcomes. Moreover, these teacher expectations indirectly significantly affect academic performance and students' psychosocial attitudes, including motivation, self-confidence, and emotional well-being.[58,59] Nevertheless, when these expectations and pedagogical approaches are linked to ideas in genetic determinism and genetic essentialism, the significant potential that should be realised may instead foster a pessimistic perspective on educational reform.

In its development, convictions regarding genetic determinism and genetic essentialism also impact the healthcare sector, evident in how individuals evaluate stigma towards patients, evaluations of genetic disorders, and presuppositions about the suitability of medical care or treatment based on inherent biological conditions. Research indicates that beliefs in genetic determinism and genetic essentialism significantly affect health-related factors, including substantial psychological effects on patients,[61] attitudes and professionalism in healthcare,[62] the development of ethical considerations in genetic counselling and patient care,[34,63] and the shaping of societal attitudes towards individuals with genetic disorders.[55] Content analysis shows increasing news regarding race, genetics, and disease concurrent with the development of the genomic revolution.[13] Roth elucidates that the content in concern predominantly promotes racial ideologies by stating that genetic factors contribute to disparities in health outcomes among different races.[13]

Another research investigation indicated that genetic determinism, which interprets genes as predominantly influencing behaviour and health outcomes, can lead to fatalistic attitudes among individuals with genetic diseases.[6,64] A patient who accepts a genetic determinism perspective will show reduced commitment to therapy and a reduced inclination to follow medical recommendations.[64] In the realm of mental health, particularly regarding schizophrenia, genetic explanations may foster the perception that the illness is impossible to mitigate, resulting in patients expressing a more depressing perspective on the prognosis of genetically based disorders.[14] The acceptance of genetic essentialism could worsen the fatalistic perspective, hence strengthening the social stigma against individuals with diseases. Patients with schizophrenia frequently encounter stigmatisation in multiple forms, including increased public perceptions of risk and an intensified inclination to maintain social distance from those with the condition.[65] Under larger circumstances, this hereditary attribution may result in associative stigma, whereby the close family of patients also experiences this stigmatisation.[65] Moreover, the presence of genetic essentialism bias could guide medical students in delivering early diagnoses of severe health disorders, hence potentially affecting clinical practice adversely.[66]

Genetic determinism and essentialism beliefs are not restricted to the formal area; they also impact culture, business, sports, and mental health. In the cultural area, genetic beliefs can reinforce specific historical or ethnic stereotypes as hereditary characteristics, strengthening social inequality by claiming the inherent superiority of some cultural characteristics and legitimising the marginalisation of other groups. In the business sector, ideas in genetic determinism and genetic essentialism could be the foundation for the concept that hereditary variables fundamentally determine an individual's success or failure. This deterministic perspective can significantly restrict the capacity for creativity and individual flexibility within the workplace.[67,68] Then, traits and skills are viewed as immutable, and the capacity for individuals to engage in creative problem-solving and innovation decreases significantly. Furthermore, when an essentialist perspective reinforces genetic determinism, it may generate resistance to change because employees or managers may perceive that specific positions or activities are intrinsically appropriate exclusively for certain individuals based on their genetic makeup.[69,70] More broadly, the rise of these deterministic and essentialistic viewpoints might impede organisational flexibility and responsiveness to market developments.[70]

Inequality caused by genetic determinism and essentialism can manifest in sports, where terms like "natural runner" or "champion gene" act as a sort of essentialization of athletic performance.[71,72] Inequalities may arise in player-selecting in a specific sport, such as football.[47] African players are perceived to possess greater opportunities in this sport due to their predominant physical attributes. African players are perceived to possess superior muscular mass, enhanced speed, and stronger performance compared to Europeans, making them particularly well-suited for positions that demand more physical strength. Additionally, inequality caused by genetic determinism and essentialism may manifest in the psychological aspect through the belief that the capacity to endure pressure or achieve specific psychological achievement is linked to an individual's genetic predispositions.[15] These results indicate that genetic determinism and essentialism are not only conceptual but also significantly influence the development of socially damaging attitudes.

Regarding policy, beliefs in genetic determinism and essentialism can influence students' attitudes toward genetic testing and genetic data protection (figure 3). In this genomic era, genetic testing is the most popular means for laypeople to connect with the genomic field. However, it is not widely recognized that this testing has the potential to increase determinist and essentialist attitudes that underpin racial behaviour in various contexts.[13] According to the data presented in Figure 3, the domain of genetic testing and protection takes

up a major visual segment within the hierarchy, indicating that students show considerable attention to the application of genetic data in policy making, particularly concerning potential misuse, disparities in access, and infringements of individual rights. The perspective of genetic determinism argues that genetic information possesses inherent privileges, therefore reflecting an individual's biological identity and significantly influencing their future.[73] According to this viewpoint, specific actions are necessary to advance privacy protection and stop discrimination based on genetic information.[63] Within this framework, there is a perceived urgency for regulatory actions to prevent genetic discrimination and ensure the protection of personal data. The following student response illustrates this concern:

"Because this genetic information is so personal and could be misused if it falls into the wrong hands, I feel there needs to be strict protection of a person's genetic data. It could be used for discrimination, for example, in insurance or employment"

This narrative underscores how essentialist thinking informs students' policy preferences, particularly in relation to privacy and the social consequences of genetic data.

Based on student narratives, there seems to be worry about the possible abuse of genetic data, indicating students' early understanding of bioethical issues and inequality in genetic policy. In his study, Condit demonstrated that individuals tend to use essentialist or deterministic reasoning when it serves them for purposes such as safeguarding advantageous behaviours or avoiding mistakes, thereby meeting contextualized individual desires.[23] Additional research has indicated that particular mechanisms associated with essentialist views could promote bias towards certain groups and discrimination against others.[1,32,48] Moreover, the phrase in students' narratives regarding genetic information, "if unauthorized individuals access it," may reflect an awareness of the power dynamics among individuals, the state, and companies, particularly with privacy infractions and biometric surveillance.

The designation of the insurance and employment fields as susceptible to discrimination suggests that students understand how genetic predisposition can be simplified into a rigid social categorization mechanism, ignoring contextual factors and reinforcing biological determinism. This issue underscores the necessity of a regulatory framework that ensures the right to genetic information, not only for data protection but also to prevent discriminatory practices that might worsen inequality in access to services and civil rights more generally.[57,63] Some policies have even restricted the use of genetic information by third parties, such as health institutions, insurance companies, and employers.[28,57] In this framework, genetic determinism and essentialism are not simply individual perspectives but have evolved into intellectual paradigms that are capable of influencing policy decisions with significant implications for society. Without principles of equality, privacy, and sufficient protection, policies dependent on genetic factors may lead to biologically driven social exclusion across multiple life domains.

Efforts to Mitigate Racism resulting from Genetic Determinism and Genetic Essentialism Through the Interpretation of Genome Variation

This concept of genomic variation has the ability to reduce numerous aspects of racial attitudes. The concept of genomic variety, which comprises biological, phenotypic, physical, environmental, and other diversity components, is not only a biological domain but can serve as an essential framework for decreasing the narrative of genetic determinism and essentialism. This finding is consistent with prior studies indicating that research on genomic diversity has shown the intricacies of gene interactions with environmental influences, affecting reductionist deterministic perspectives.[1,37] Another study found that students with high genomic literacy greatly reduced essentialist attitudes after studying human genetic variation, particularly when the learning underlined the mistakes of essentialist assumptions.[74] Technological advances such as next-generation sequencing (NGS) also perform an important role in supporting several other findings because this technology reveals various single nucleotide variation diversities that do not always have implications for specific biological functions, making it challenging to make deterministic claims that link genes directly to individual traits or identities.[53,75] Furthermore, the real-world evidence that has been shown supports one conclusion: a critical view of genomic variation can help confront racist genetic claims about things like physical ability, intelligence, creativity, race, career advancement, and social status.

In a more specific relationship pattern, the three main theme paths in figure 4 (represented by Research Questions (RQ1, RQ2, and RQ3) reveal that all genetic variation components can reduce racist ideas. In RQ1, all dimensions of genetic variation are evaluated in relation to deconstruction efforts against categories of racism, including ability, race, intelligence, ethnicity, views, prejudice, potential, and access to education. Although the decrease of the "outlook" aspect appears to be more limited in RQ2, the relationship is still present. Meanwhile, RQ3 reveals that the three primary components, including diversity, phenotype, and environment, have a direct impact on eliminating racist bias against ability, race, views, prejudice, potential, education, and employment. This state demonstrates that genetic variety is not just a scientific concept but also has an epistemic ability to reduce essentialist beliefs predicated on racial biases. The following excerpts are direct

statements from student participants, illustrating their recognition of individual genetic differences and their rejection of racial superiority based on such differences:

"Skin colour, height, and hair are simply minor variations of genetic expression. All humans have identical DNA. One cannot claim the superiority of one race over another only based on physical differences".

"All humans share a common ancestry. Human genes interact when identified. Thus, nothing is genuinely pure or superior to the rest".

These responses highlight a growing awareness among students that variation in genetic expression should not serve as justification for racial hierarchies or discriminatory attitudes.

The study of genome variation, focusing on the complexity and variability of genetic influences, maintains considerable promise for enhancing individual genetic literacy.[37] However, to realize this significant potential, targeted educational interventions are required, particularly genetic learning that emphasizes understanding not only the biological aspect but also its integration with the socio-environmental dimension. Moreover, a clear comprehension of genome variation enables students to understand that human traits are not solely dictated by genes but developed through dynamic interactions with social and environmental factors. This viewpoint may further diminish the beliefs of genetic determinism and genetic essentialism, which reduce human identity to simply genetic products.[76,77] Implicationally, the transition toward a more humanistic mindset must be consistently empowered because it strategically reduces biological stereotypes and creates a way for social justice.[77] Thus, genetic education, which includes a comprehensive understanding of genome variation, contributes to increasing genetic literacy and serves as an epistemological structure that reduces genetic narratives based on genetic determinism and essentialism, which are at the base of racism.

CONCLUSIONS

Students' narratives reveal that genetic knowledge is often framed within deterministic and essentialist assumptions that naturalize individual differences, reinforce social hierarchies, and rationalize inequality. Such framings expose how genetic concepts are not merely scientific but embedded within sociocultural logics that shape attitudes toward discrimination and public policy. At the same time, recognizing genomic variation emerges as a conceptual resource potentially disrupting essentialist thinking. However, this potential remains underutilized in educational settings, where genomic diversity has yet to be fully integrated as a foundation for critical and inclusive reasoning in genetics learning.

Limitation

Genetic learning has been extensively researched; however, gaps remain in our comprehension of the phenomenon. A comprehensive examination of how curriculum design, pedagogical methods, and material presentation might be strategically utilized to mitigate students' tendency towards genetic determinism and essentialism has yet to be conducted. This implication creates opportunities for additional research to design and evaluate diverse educational components, including curricula, learning models, instructional materials, and genetic learning media, specifically focused on enhancing comprehension of biological diversity while reducing genetic simplification or stereotypes.

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CONFLICT OF INTEREST

None

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