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A Latent Class Approach to Profiling Genetic Literacy Among Emirati Adults in a Precision Medicine Context

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Abstract

Background

National precision medicine initiatives require public understanding of probabilistic genetic risk, yet populations are heterogeneous in knowledge, confidence, and attitudes. Simple demographic segmentation may miss complex patterns shaping engagement with genomic information. This study applied latent class analysis (LCA) to identify genetic literacy profiles among participants in a national genomics program, focusing on knowledge-confidence alignment.

Methods

A cross-sectional survey of 509 Emirati adults (aged 18–64) was conducted in Abu Dhabi from January 20 to February 3, 2025. LCA used indicators of objective genetic knowledge (four true/false items assessing penetrance, probabilistic risk, gene-environment interaction, and heritability), self-perceived knowledge, demographics, program participation, and attitudinal variables, including worry about results and willingness to change lifestyle.

Results

LCA identified 10 classes with different configurations of knowledge, confidence, and engagement. The most striking finding was systematic misalignment between knowledge and confidence. Class 2 (8.4%) (highly educated, engaged, middle-aged male professionals) demonstrated the lowest objective knowledge (16.5% correct) despite high self-reported confidence. Conversely, Class 8 (10.5%), middle-aged women with chronic disease and lower education, demonstrated high objective knowledge (58.5%), potentially driven by personal health experience. The largest class (Class 5, 22.6%) comprised knowledgeable, engaged middle-aged adults.

Conclusions

Genetic literacy is not distributed along simple demographic lines. LCA reveals that knowledge, confidence, and engagement combine in complex patterns conventional demographic targeting cannot capture. Identifying "confident but uninformed" profiles has direct implications for how precision medicine programs design education and communicate results. Different profiles require different interventions: confidence-building for the knowledgeable but worried, misconception correction for the confident but uninformed.

Background

The translation of precision medicine from research to clinical practice depends critically on public genetic literacy (1, 2). National genomics initiatives, including the Emirati Genome Program (EGP), aim to provide individuals with actionable information about genetic risk for common diseases(3). However, the value of this information depends on recipients' understanding of its probabilistic nature and their appropriate response (4, 5). Misconceptions, particularly genetic determinism, the belief that genetic risk is fixed and unmodifiable, can undermine the preventive goals that justify these programs (6, 7).

Research on public understanding of genetics has typically examined knowledge at the population level or stratified by simple demographic variables such as age, education, and sex(8). While this approach has revealed important patterns, it may obscure the heterogeneity that characterizes real populations. Individuals differ not only in what they know, but in how confident they feel about their knowledge, how worried they are about genetic results, and how willing they are to act on genetic information (9, 10). These dimensions may combine in complex patterns that are not captured by examining each variable in isolation.

The phenomenon of knowledge-confidence misalignment, in which individuals' confidence in their understanding does not align with their actual knowledge, is particularly relevant to precision medicine education (11). Prior research has documented a general tendency toward overconfidence in genetic knowledge, with parallels to the Dunning-Kruger effect observed in health literacy domains (12, 13). However, less is known about whether distinct population profiles exist with characteristic patterns of alignment or misalignment, and whether these profiles have different implications for educational intervention.

Latent class analysis (LCA) offers a methodological approach suited to this question (14, 15). Unlike variable-centered approaches that examine associations among variables, LCA is a person-centered approach that identifies subgroups of individuals who share similar response patterns across multiple indicators (16). This can reveal population heterogeneity that would be masked by examining means or proportions at the aggregate level (17). LCA has increasingly been applied in healthcare research to identify meaningful population segments for targeted interventions (18, 19).

This study applied LCA to survey data from a population engaging with the EGP to identify distinct profiles characterized by different configurations of genetic knowledge, confidence, and attitudes. The Emirati population represents an important but understudied context, as Arab populations remain substantially underrepresented in genomic research (20, 21). The objectives were: (1) to determine whether meaningful latent classes exist within this population; (2) to characterize each class in terms of knowledge-confidence alignment; and (3) to derive implications for targeted educational strategies.

Methods

Compliance with Ethics Guidelines

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). **Informed consent was obtained from all patients for being included in the study.Study Design and Population**

This cross-sectional survey assessed genetic knowledge, attitudes, and practices among Emirati nationals in Abu Dhabi. A total of 509 participants aged 18–64 years completed the survey between January 20 and February 3, 2025. The sample included both EGP participants (n = 303, 60%) and non-participants (n = 206, 40%). The study protocol was approved by the Abu Dhabi Health Research and Technology Committee.

Measures

Objective genetic knowledge was assessed using four true/false statements designed to capture key misconceptions relevant to precision medicine (6, 22): (1) "If a person carries a disease gene, they will develop the disease" (False; penetrance); (2) "A higher genetic risk guarantees that someone will get the disease" (False; probabilistic risk); (3) "Living a healthy lifestyle has no impact on someone with an increased genetic risk for a preventable disease" (False; gene-environment interaction) (23); (4) "Healthy parents can have a child with a genetic disease" (True; heritability). A composite knowledge score was calculated as the percentage of correct responses.

Self-perceived knowledge was measured by asking respondents to rate their understanding of genetic testing on a four-point scale: None, Low, Moderate, or High.

Attitudinal variables included worry about receiving genetic results (worried vs. not worried) and willingness to change lifestyle based on genetic information (willing vs. not willing).

Demographic and contextual variables included age group (18–24, 25–34, 35–44, 45–54, 55–64), sex, educational attainment, parental status, employment status, presence of chronic non-communicable diseases, family history of genetic conditions, EGP participation status, and influence of cultural/religious beliefs on views about genetics.

Latent Class Analysis

LCA was conducted to identify subgroups with distinct patterns across the measured indicators (14, 15). Model selection was guided by standard fit indices, including the Bayesian Information Criterion (BIC), Akaike Information Criterion, and entropy (16). Models with 2 through 12 classes were estimated, and the optimal number of classes was determined by identifying the model that balanced parsimony, interpretability, and fit (24). Class membership was assigned based on maximum posterior probability.

Following class enumeration, each class was characterized by examining the conditional response probabilities for each indicator variable and the mean knowledge score. Classes were interpreted and labeled based on their distinctive features and, where applicable, grouped into broader typologies reflecting knowledge-confidence alignment patterns (17).

Results

Sample Characteristics

The 509 respondents were evenly distributed by sex (50% female). Age distribution was weighted toward younger and middle-aged adults: 18–24 years (26%), 25–34 years (26%), 35–44 years (27%), 45–54 years (15%), and 55–64 years (6%). Educational attainment was high, with 43% holding bachelor's degrees and 38% holding diplomas or certificates. The majority (60%) were EGP participants.

Model Selection

Model fit indices supported a 10-class solution, which provided the best balance of fit and interpretability (24). This solution achieved adequate entropy (> 0.80), indicating clear class separation, and all classes had sufficient membership for stable parameter estimation (smallest class = 5,7%, n = 29). The 10-class solution was substantially better than simpler models in terms of BIC and revealed meaningfully distinct profiles that would have been collapsed in solutions with fewer classes.

Latent Class Profiles

Table 1 presents the characteristics of each latent class. The 10 classes varied substantially in their configurations of knowledge, confidence, engagement, and demographic composition.

Table 1. Latent Class Profiles: Characteristics and Knowledge-Confidence Patterns (N=509)

Class	Prevalence	Key Demographic Features	Knowledge Score	Profile Summary
1	5.7%	Young (18–24), Male, Low parenthood, High EGP engagement	72% (High)	Knowledgeable, worried, and engaged young adults with low cultural/religious influence on genetic views
2	8.4%	Middle-aged (35–54), Male, Parents, High education, High EGP engagement	16,5% (Low)	Confident but low-knowledge professionals; unconcerned about results; high cultural/religious influence
3	10.9%	Young adults (25–34), Female, Parents, High education, High EGP engagement	33,6% (Moderate)	Engaged young families; moderately knowledgeable; not worried; high cultural/religious influence
4	6.3%	Older (55–64), Male, Parents, Low education, High chronic disease, Low EGP engagement	34,4% (Moderate)	Disengaged older adults with health concerns; moderately knowledgeable; high cultural/religious influence
5	22.6%	Middle-aged (35–44), Mixed sex, Parents, High employment, Moderate EGP engagement	51,9% (High)	LARGEST CLASS: Knowledgeable, worried, and engaged middle-aged adults; the "core audience" for precision medicine
6	11.8%	Young (18–24), Female, Low parenthood, Low education, Low EGP engagement	41,8% (Moderate)	Disengaged, less-educated young women; moderately knowledgeable; less willing to change lifestyle
7	6.3%	Young adults (25–34), Male, Low parenthood, High employment, Moderate EGP engagement	24% (Low)	Unmarried employed young men; low knowledge but HIGH willingness to change lifestyle ("willing but uninformed")
8	10.5%	Middle-aged (45–54), Female-leaning, Parents, Low education, High chronic disease	58,5% (High)	Knowledgeable older adults with health issues; worried and willing to act; knowledge may be driven by personal health experience
9	8.2%	Young (18–24), Male, Low parenthood, High employment, High EGP engagement	26% (Low)	Engaged but low-knowledge young professional men; moderately concerned ("confident but uninformed")
10	9.3%	Young adults (25–34), Female-leaning, High education, High employment	58,3% (High)	Highly knowledgeable and engaged young professionals; very worried; low cultural/religious influence

Knowledge scores reflect percentage of correct responses across four genetic knowledge items.

Knowledge-Confidence Alignment Patterns

The most striking finding was the systematic misalignment between knowledge and confidence observed across classes. Three broad typologies emerged:

Confident but uninformed (Classes 2, 9): These classes represented 16,6% of the sample. Class 2 is particularly notable: middle-aged male professionals with high educational attainment and high EGP engagement demonstrated the lowest objective knowledge (16.,%) of any class. Class 9, young employed men with high program engagement, similarly showed low knowledge (26%) despite active participation. Both classes reported high self-perceived understanding. This pattern is consistent with the Dunning-Kruger effect documented in health literacy domains (12, 13) and presents a challenge for educational intervention: individuals who believe they already understand the material are less likely to recognize their need for additional learning.

Knowledgeable and engaged (Classes 1, 5, 8, 10)

These classes represented 48,1% of the sample, nearly half the population. Class 5, the largest single class at 22,6%, comprised knowledgeable middle-aged adults who were worried about results and engaged with the program. Classes 1 and 10 represented highly knowledgeable younger adults differentiated by gender (young men vs. young professional women). Class 8, knowledgeable older adults with chronic disease, suggests that personal health experience may be a powerful driver of genetic literacy. These classes represent the "core audience" for precision medicine, individuals whose knowledge and engagement are aligned.

Willing but uninformed (Class 7): Representing 6,3% of the sample, this class of unmarried young employed men showed low knowledge (24%) but high willingness to modify lifestyle based on genetic information. This profile presents a particular opportunity: their openness to action, combined with low knowledge, suggests they would benefit from educational intervention that could produce meaningful behavior change (23, 25).

Disengaged (Classes 4, 6)

These classes represented 18,1% of the sample. Class 4 comprised older adults with chronic diseases who were not engaged with the EGP despite having health conditions that would make genetic information relevant. Class 6 comprised young women with low education and low program engagement. Both showed moderate knowledge levels but low engagement, suggesting barriers to participation that may require different intervention approaches.

Table 2
Summary of Knowledge-Confidence Typologies

Typology	Classes	% of Sample	Educational Implications
Confident but uninformed	2, 9	16,6%	Require misconception correction; direct instruction may be rejected; consider interactive approaches that reveal knowledge gaps
Knowledgeable and engaged	1, 5, 8, 10	48,1%	Ready for detailed information; can serve as community champions; may need reassurance about appropriate worry levels
Willing but uninformed	7	6,3%	High potential for behavior change; prioritize foundational education; openness to learning is an asset
Moderate knowledge, engaged	3	10,9%	Build on existing engagement; targeted correction of specific misconceptions
Disengaged	4, 6	18,1%	First build relevance and trust; address barriers to engagement before educational content

Discussion

Principal Findings

This LCA of genetic literacy in an Emirati population engaging with a national genomics program revealed substantial heterogeneity that would be obscured by conventional demographic analysis. The 10 identified classes differed not only in their level of genetic knowledge but in the configuration of knowledge, confidence, engagement, and demographic characteristics. The finding of systematic knowledge-confidence misalignment, with some classes demonstrating high confidence despite low knowledge and others demonstrating high knowledge despite low confidence, has direct implications for how precision medicine programs approach public education (1, 26).

The identification of Class 2 is particularly consequential. This class, comprising middle-aged male professionals with high education and active program engagement, represents exactly the population that most programs would assume does not require intensive educational intervention. Yet this class demonstrated the lowest objective knowledge of any group (16,5% correct). The combination of professional status, high education, and program participation appears to create a confident self-assessment that is disconnected from actual understanding. This pattern is consistent with the Dunning-Kruger effect in health literacy (12, 13) and suggests that familiarity with genomic concepts, gained through program enrollment, media exposure, or general education, may create an illusion of understanding.

Conversely, Class 8, middle-aged women with chronic disease and lower formal education, demonstrated high knowledge (58,5%). This suggests that personal health experience may be a more powerful driver of genetic literacy than educational attainment. Individuals managing chronic conditions may have encountered genetic concepts through their healthcare experiences in ways that produced genuine understanding rather than superficial familiarity.

Implications for Educational Strategy

The existence of distinct profiles with different knowledge-confidence configurations implies that a uniform educational approach will be suboptimal (27, 28). Different profiles require fundamentally different interventions:

For the confident-but-uninformed profiles (Classes 2 and 9), direct didactic instruction may be ineffective or even counterproductive (13). Individuals who believe they already understand the material are unlikely to engage seriously with educational content that contradicts their self-assessment. Alternative approaches might include interactive tools that reveal knowledge gaps through prediction tasks, peer-to-peer discussion formats that challenge beliefs without direct confrontation, or case-based learning that allows individuals to discover misconceptions through application.

For the willing-but-uninformed profile (Class 7), the educational priority is different. These individuals' openness to behavior change represents an opportunity, but acting on genetic information without adequate understanding could lead to inappropriate decisions. Foundational education that builds correct conceptual models before results are returned may be particularly valuable for this group. Evidence demonstrates that lifestyle modification can substantially reduce disease risk even in individuals at high genetic risk (23, 25).

For the disengaged profiles (Classes 4 and 6), the challenge is engagement before education. Class 4, older adults with chronic disease who are not participating in the EGP, represents a population for whom genetic information could be clinically relevant. Understanding barriers to engagement (which may include accessibility, trust, or perceived relevance) is a prerequisite for educational intervention (26).

For the knowledgeable-and-engaged profiles (Classes 1, 5, 8, 10), the educational need may be less about knowledge building and more about appropriate calibration of worry and support for decision-making (5, 29). Class 10, for example, comprises highly knowledgeable young professionals who report high levels of worry. For this group, educational content that contextualizes risk and provides frameworks for decision-making may be more valuable than content focused on correcting misconceptions.

Comparison with Prior Research

The finding of knowledge-confidence misalignment is consistent with prior research documenting overconfidence in health and genetic knowledge among both the public and healthcare professionals (12, 13, 30). However, the use of LCA allowed us to move beyond documenting this phenomenon at the

aggregate level to identifying specific population profiles characterized by different patterns of misalignment. This advances the literature by demonstrating that the confidence-knowledge gap is not uniformly distributed but concentrated in identifiable subgroups (17, 19).

The class structure also resonates with theoretical models of health behavior. The identification of distinct "worried" and "not worried" profiles with similar knowledge levels suggests that affective responses to genetic risk information may vary independently of cognitive understanding (5). This has implications for risk communication, which must address both informational and emotional dimensions (29).

Strengths and Limitations

This study has several strengths. The application of LCA to genetic literacy is novel and revealed population heterogeneity that would be masked by variable-centered approaches (14, 15). The sample included both program participants and non-participants, allowing comparison across engagement levels. The use of objective knowledge assessment alongside self-perceived understanding enabled a direct examination of the alignment between knowledge and confidence.

Several limitations should be noted. The cross-sectional design captures a single timepoint and cannot establish how profiles develop or change over time. The Abu Dhabi sample may not generalize to other populations or cultural contexts. The 10-class solution, while statistically supported, represents one of multiple defensible solutions; alternative class numbers might yield different interpretations (24). The knowledge assessment, while covering fundamental concepts, was limited to four items and may not capture the full spectrum of genetic literacy (8). Finally, class membership is probabilistic, and some individuals may have been assigned to classes with which they have only partial membership.

Conclusions

Latent class analysis reveals that genetic literacy is not distributed along simple demographic lines. Within a population participating in a national precision medicine program, we identified 10 distinct profiles characterized by distinct configurations of knowledge, confidence, engagement, and demographic characteristics. The most actionable finding is the identification of "confident but uninformed" profiles, individuals who believe they understand genetics but demonstrate poor objective knowledge. These individuals, often highly educated and actively engaged with genomics programs, may be the most difficult to reach through conventional educational approaches (13).

These findings argue for a segmented approach to precision medicine education (28). Rather than uniform messaging, programs should develop differentiated content and delivery strategies tailored to each profile's specific characteristics. For the confident-but-uninformed, interactive approaches that reveal knowledge gaps may be more effective than direct instruction. For the willing-but-uninformed, foundational education should precede results communication. For the disengaged, engagement-

building must precede education. For the knowledgeable-and-engaged, the focus should shift from knowledge building to decision support (5, 29).

As precision medicine moves from research to routine clinical practice, understanding the heterogeneity of the populations being served becomes increasingly important (1, 2, 26). The methods and findings presented here offer a template for characterizing this heterogeneity and tailoring educational strategies accordingly.

Declarations

Conflicts of Interest

Thiago Guimarães Osório declares he has no conflict of interest. Terrence Lee-St. John declares he has no conflict of interest. Needa Qureshi declares she has no conflict of interest. Leanne Cassidy declares she has no conflict of interest. Laura Buckley declares she has no conflict of interest. Salma Geissah declares she has no conflict of interest. Bartlomiej Piechowski-Jozwiak declares he has no conflict of interest. Erik Koornneef declares he has no conflict of interest. Nicole Sirotin declares she has no conflict of interest.

Author Contribution

TGO conceived and designed the study and wrote the original manuscript draft. TLSJ contributed to study planning and conducted the data analysis. NQ, LC, and BPJ contributed to study planning and execution, and LB contributed to study execution. SG contributed to manuscript editing. EK and NS provided supervision. All authors read and approved the final manuscript.

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Data Availability

The Emirati Genome Program survey data that support the findings of this study are held by the Institute for Healthier Living, Abu Dhabi (IHLAD). Because the dataset contains personal health-related information governed by UAE Federal Law No. 2 of 2019 on the Use of Information and Communication Technology (ICT) in Health Fields, and access was granted under approval from the Abu Dhabi Health Research and Technology Committee for the current study, restrictions apply and the data are not

publicly available. The data are, however, available from the corresponding author upon reasonable request and with the permission of IHLAD [and the Abu Dhabi Department of Health].

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