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Precision Education Revolution: Identifying Future Requirements for Integrating Genomics into Educational Practices

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Abstract

Genomics researchers have made a groundbreaking discovery regarding the relationship between a specific genome and various aspects of behavior, cognitive ability, skill acquisition, and educational attainment. This study, which builds on the contributions of researchers in precision education and educational genomics, aims to explore the promising potential of utilizing genomics in the application of precision education and to identify the priority future requirements that need to be considered for the successful integration of genomics in precision education from an educational perspective. It is worth noting that these requirements have only been discussed from a medical perspective in the context of precision medicine, etc., and no study has aimed to identify the future requirements that need to be considered for the successful integration of genomics in precision personalized education from an educational perspective. The study concluded that integrating genomics into educational systems is of paramount importance and that precision education based on genomics represents the future stage in delivering educational services. The study also identified four categories of future requirements, 22 in total, with the priority of each requirement when applying precision education based on genomics in practice.

Keywords: Genomics; Educational genomics; Precision education; Future of education

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ثورة التعليم الشخصي الدقيق: تحديد المتطلبات المستقبلية لدمج علم الجينوم في الممارسات التعليمية

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ملخص

لقد حقق الباحثون في مجال علم الجينوم اكتشافًا بالغ الأهمية، يتعلق بتحديد العلاقة بين جينوم معين وجوانب مختلفة من السلوك الإنساني، والقدرة المعرفية، واكتساب المهارات، والتحصيل الدراسي. تهدف هذه الدراسة، استنادًا إلى إسهامات الباحثين في التعليم الشخصي الدقيق وعلم الجينوم، إلى الكشف عن الإمكانات الواعدة للاستفادة من علم الجينوم في تطبيق التعليم الشخصي الدقيق، وتحديد أولويات المتطلبات المستقبلية التي تجب مراعاتها لتحقيق الدمج الناجح بين علم الجينوم والتعليم الشخصي الدقيق من منظور تربوي. وهذه المتطلبات لم تسبق مناقشتها إلا من المنظور الطبي في إطار الطب الدقيق، وغيره من التخصصات العلمية الأخرى، ولا توجد دراسة استهدفت تحديد المتطلبات المستقبلية التي تجب مراعاتها لتحقيق الدمج الناجح بين علم الجينوم والتعليم الشخصي الدقيق من منظور تربوي، وهذا ما يؤد على أهمية هذه الدراسة. وقد أبرزت الدراسة الأهمية البالغة لدمج علم الجينوم في النظم التعليمية، وتوصلت إلى أن التعليم الشخصي الدقيق المستند إلى علم الجينوم، يمثل المرحلة المستقبلية في تقديم الخدمات التعليمية، كما حددت أربع فئات من المتطلبات المستقبلية، تتضمن 22 متطلبًا، مع تحديد أولوية كل متطلب عند تطبيق التعليم الشخصي الدقيق المستند إلى علم الجينوم في الواقع العملي.

الكلمات المفتاحية: علم الجينوم، علم الجينوم التربوي، التعليم الشخصي الدقيق، مستقبل التعليم

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1. Introduction: Ushering in Precision Education with Personal Genomics

Personal genetics, often described as an “unstoppable force,” is rapidly becoming more accessible to the public due to decreasing costs. Now, numerous companies offer genetic testing or “genome scans” to individuals seeking information about their ancestry, disease risks, behavioral tendencies, and even athletic potential. While still in its infancy, the field of personal genomics holds immense promise, evidenced by its various applications in healthcare (Kung & Gelbart, 2012).

The last five years have witnessed a surge in interest in integrating genetic information into education. This integration holds the potential to personalize learning experiences and optimize educational processes (Sabatello, 2018; Kovas et al., 2016; Panofsky, 2015; Asbury, 2015; Thomas et al., 2015; Asbury & Plomin, 2013). Notably, a 2018 study published in Nature Genetics by the SSGAC and a consumer genetics company demonstrated that educational attainment has a heritable component and is linked to various social, economic, and health outcomes (Lee, 2018).

While accounting for individual variations in learning aptitude is a crucial issue in educational research, the role of genetic factors is often ignored. The field primarily focuses on developing uniform approaches to suit all students, which challenges educators who recognize that each student possesses a unique profile of psychological, cognitive, and emotional characteristics. According to genetic research, each learner has a distinct genetic makeup comprising a unique DNA sequence, specific gene expression patterns, and a naturally individualized way in which their genes interact with the environment (Kovas et al., 2016).

Therefore, adapting the educational process based on personal genetic data holds promise for better meeting individual needs and improving academic achievement (Krasa & Shunkwiler, 2009; Kovas et al., 2016). However, educational success requires a multifaceted approach beyond single interventions or programs. Key elements include student ability and motivation, teacher expertise, instructional methods, and curriculum design (Kovas et al., 2016). While correlations exist between genetic differences and human traits, both physical and mental, including educational attainment, recent research has focused on understanding the specific genetic markers linked to aspects such as intellectual capacity, learning difficulties, and verbal skills. The growing interest in using genetic research to develop educational processes and systems should not overshadow the crucial role of the environment in shaping individual growth and learning outcomes (Baron-Cohen et al., 2014; Docherty et al., 2010).

1.1. Future Implications and Challenges of the Educational Genomics Revolution

Recently, Educational Genomics has emerged as a new research field that investigates how detailed information about the human genome – specifically, DNA variables – can be used to determine certain educational attributes, such as reaction time, memory, academic success, and learning abilities. It is believed that educational genomics will contribute in the future by enabling educational institutions to create specially designed curriculum programs based on the learner’s DNA profile. Information about DNA variants can also be used to predict the distinguished capabilities of the learner so that they can be best developed within a tailored, rich environment in the classroom (Gaussian, 2016). Although research findings emphasize that individual learning differences, genetics, and their implications for education are rare. Recent years have witnessed an interest in research that investigates personalized medicine, which investigates genetic differences among people to predict potential health problems, thus enabling physicians to modify treatment and prevention methods (Collins, 2010). Similarly, the same information can be used to develop the field of educational genomics and it holds immense potential for the advancement of the subject, potentially paving the way for personalized learning approaches (Conley & Fletcher, 2017; McCarthy & Mahajan, 2018; Plomin, 2018), so that every child can be allowed to reach his/her full potential (Gaussian, 2016).

Martschenko et al. (2019) discussed developments in genetics research and their potential implications for education. They emphasized that genetics plays a significant role in understanding individual growth and human behaviors. They also believed that the results of genetics research would influence various human activities. They emphasized that the role of the environment in education is no less important than the role of the human genome, as individual skills can only be developed by providing the appropriate environment. Practitioners of educational genomics and behavioral genetics identified that the interaction between educational environments and learners' distinctive genetic makeup plays a crucial role in shaping learning abilities, educational achievement, and motivational levels, leading to substantial variations among individuals (Kovas et al., 2007).

Genetics research can also contribute to deepening the understanding of learning difficulties and development paths that can contribute to how educators can deal with different learning difficulties of individuals by providing information that contributes to identifying appropriate intervention strategies for each learner individually. It can also contribute in the long term to forecasting risks at the individual level (Daphne et al., 2019). Recent research suggests that incorporating genetic insights into education could revolutionize learning, allowing us to cater to individual needs and maximize potential. Research by Asbury and Plomin (2013) proposed three key strategies for educators and policymakers: acknowledging and embracing individual differences in abilities, tailoring educational approaches to individual genetic profiles, and mitigating the negative impacts of disadvantaged backgrounds through early intervention. Advances in molecular genetics, such as the use of microarrays for analyzing DNA markers, are illuminating the biological processes that influence gene expression in response to various environments (Plomin et al., 2012).

Genome-wide association studies (GWAS) have revealed the biological basis of learning by identifying genetic factors linked to language, reading, and math skills. (Meaburn et al., 2008). Furthermore, GWAS have uncovered genetic variations associated with educational attainment, suggesting a significant role of genes in learning ability (Rietveld et al., 2013). These advancements in molecular genetics hold promise for the early diagnosis of learning disabilities and the identification of relevant genes. This, in turn, could pave the way for personalized educational approaches tailored to individual cognitive and motivational profiles (Kovas et al., 2016).

1.2. Gene-environment Interplay

The traditional view of the impact of genetics and environment on child development has recently undergone a significant shift. Instead of adhering to a simplistic dichotomy of genes versus environment, the current perspective emphasizes the intricate interplay between genes and the environment throughout the developmental process. Contemporary research now directs its attention to examining the co-action of molecular genetic mechanisms and the environment along two pathways. The first path delves into how the environment influences gene expression through epigenetic processes, while the second path explores how genetics shape an individual's perceptions and choices in their environment, known as gene–environment correlations (Kovas & Malykh, 2016). However, it is crucial to recognize that the majority of common individual growth and human behaviors are polygenic. The development of specific learning abilities or competencies, and the degree of mastery achieved, is determined by the combination of numerous genes and the interaction between genes and the environment.

Thus, this study aims to reveal how Educational Genomics will help in developing precision education in the near future, and what the future prerequisites should be considered for ensuring successful implementation by answering the following questions:

1. How will Educational Genomics help in developing precision education experiences in the near future (next 5-10 years)?
3. What are the key future requirements that need to be prioritized for integrating genomics into precision education experiences in the near future, especially from an educational standpoint?
4. Are there statistically significant differences in the responses of the participants based on their demographic characteristics?

2. Literature Review

2.1. Precision Education: Definition and Structural Components

The prefix "precision" has become increasingly prevalent across distinct domains of scientific and technological research, encompassing fields such as medicine, agriculture, and education (Kuch et al., 2020). New forms of knowledge are being generated through the application of "precision" technologies, which involve the creation of new data and sophisticated measurement techniques to precisely assess target cases and implement interventions (Williamson, 2019a).

Precision education is both an interdisciplinary 'science of learning' and an educational model informed by the sciences of the human mind, brain, and genome. Williamson (2019a) defines precision education as a burgeoning fusion of psychological, neuroscientific, and genetic proficiency that is underway, with a specific focus on leveraging advanced computational technologies to generate "intimate data" about students' bodies and their biological correlations with the learning process.

At its core, precision education revolves around customizing preventative and intervention approaches for individuals, guided by the most robust and current evidence. It also utilizes innovative research designs to answer the fundamental question: "What intervention worked with whom and how did it work?" This is achieved through deep analysis of the root causes of specific scholastic, emotional, social, and physical health problems. This analysis informs the development of suitable, tailored, and personalized prevention and intervention practices that match each child's unique needs (Cook et al., 2018).

The future aspiration for precision education is to be firmly grounded in an interdisciplinary science of learning that informs the implementation of precise practices in education. This aims to ultimately overcome the shortcomings of the “one size fits all” model, where one educator delivers the same material to a group of learners without individualization. It is important to note that precision education is still in its early stages of development, and there is no single, universally agreed-upon definition. However, a common theme amongst proposed definitions is the emphasis on providing adaptive, immediate, precise, detailed, and contextualized personalized interventions (Lian & Sangarun, 2017).

One of the promises of precision education is the increased use of learner data to inform and personalize educational practices (Williamson, 2019b). It shares a core tenet with precision medicine: the desire to improve personalized interventions based on individual assessments, predictions, treatments, and prevention strategies for specific needs. Therefore, the primary goal of genetic-based precision education is to enhance diagnosis, prediction, treatment, and prevention strategies specifically tailored to at-risk students through individualized approaches (Lu et al., 2018; Yang, 2019).

Precision education has certain core characteristics (Mazoue, 2013):

1. Its research-based approach and methodology aim to produce learning-optimized course structures.
2. It effectively individualizes learning.
3. It centers on competencies as a basis for education.
4. It exhibits scalability in its application.
5. It proves to be cost-efficient.

The initial facet of precision education entails a meticulous analysis of the student’s challenges, delving into genuine needs that may involve deficiencies in adaptive skills, such as recognizable fluency, acquisition, or performance deficits. Environmental factors, such as the absence of instructional alignment or adult attention, can also influence skill deficits. Theoretical paradigms such as instructional hierarchy, skill-by-treatment interaction, or functional assessment may be employed in this problem analysis. The second facet revolves around flexible interventions tailored to align with individual student needs, preferences, and motivation, effectively addressing identified problems. These interventions encompass versatile multi-functional strategies personalized to suit each student‘s unique requirements. Monitoring constitutes the third pivotal element in precision education, with the objective of ongoing formative evaluation of the student’s progress resulting from the tailored intervention. The outcomes of monitoring serve as the basis for adjusting the intervention to better align with evolving needs. Collaboration, the fourth component of precision education, is considered essential for making data-driven, timely, and judicious decisions. This collaboration plays a crucial role in determining whether to modify, implement an alternative, or conclude the intervention based on the available information (Cook et al., 2018).

The researcher defines Genomics-based precision education as the design and development of educational services and opportunities that are commensurate with the characteristics of the learners. This approach enables educational practitioners to classify learners into subgroups based on their genetic profiles. Subsequently, it enables the adaptation of the educational process to personal genetic data, thereby meeting the individual needs of students and enhancing their academic achievement.

Furthermore, precision education focuses on developing and designing preventive or supportive interventions that target those who will benefit from them. This avoids exposing individuals who are unlikely to benefit from unnecessary interventions, thus preventing wasted time and resources.

2.2. How will Educational Genomics help in Developing Precision Education in the Near Future?

Genetic researchers have definitively linked genes and educational achievement, marking a significant advancement in the burgeoning field of educational genetics. Although still in its early stages, educational genomics is prompting a growing call to leverage genomic insights for crafting personalized educational approaches. This methodology envisions tailoring educational interventions to seamlessly harmonize with each child's unique genetic makeup (Grigorenko, 2007). Preliminary indications suggest a rising acceptance of genomics in education, reflecting the potential for genomic data in shaping effective interventions from birth onwards, as conceptualized by Francis Collins (Sabatello, 2018).

In the near future, genetics research may enable precision education to use individual genotypes to tailor personalized educational activities for each child. This will be achieved by investigating learning mechanisms that explain why some current teaching and learning methods work, in addition to identifying which future methods might also be effective and for whom (Thomas, 2013).

Asbury and Plomin (2013) propose that if educational systems optimize educational environments, the remaining differences between learners may be due to genetic makeup. Therefore, it is crucial to align educational environments with these genetic variations to maximize the capabilities of learners. Recent genetic studies confirm that genetic influences are not fixed; instead, they are dynamic. This means that the same genes can exhibit different expressions in different environments and at different stages of human development (Kovas et al., 2007; Kovas et al., 2013). Genetics can enable education systems to focus on specific genes among learners and develop precision education activities that can contribute to maximizing learners' potential and tailoring interventions that depend on learners 'genetic makeup' (Söderqvist et al., 2013).

Behavioral geneticist Robert Plomin and colleagues foresee "precision education" based on "genome-wide polygenic scoring" (GPS) as a potentially innovative method of customizing education. This is because polygenic scores can be used to predict a student's academic achievement directly from their DNA. As a result, the potential for early intervention and individualized learning becomes attainable.

2.3. What Genetic Data will Precision Education need to be informed about to Optimize Educational Outcomes for Learners?

Precision education requires genetic data likely related to the brain, as it is responsible for perception and learning. Therefore, the focus will be on both the brain's structure and its cognitive functions. Quantitative genetic studies highlight essential genes that precision education needs to investigate thoroughly. These include genes that impact performance in fundamental school disciplines, cognitive abilities, individual traits, mental health, physical well-being, self-efficacy, behavioral challenges, overall welfare, and perspectives on the educational environment (Krapohl et al., 2014).

2.4. The Difficulties Associated with Employing Genetic Information to Derive Tangible Applications for Precision Education

While some advocate for genomically informed precision education, the promise of readily available genetic data for personalized learning faces significant challenges and raises important ethical, legal, and social issues, such as potential misuse in educational settings (Sabatello, 2018).

Educational researchers must actively investigate approaches to tackle these challenges, anticipating the need for responsive measures. Before devising precision education methodologies, a thorough examination of privacy and insurability considerations regarding students' personal genetic data is essential. This transformative shift necessitates that educational practitioners adopt new ethical and legal obligations in managing sensitive and potentially unfamiliar confidential genetic information.

2.5. Genomicization of Precision Education: Agenda for the Future

Policymakers should closely examine the essential prerequisites for implementing genomicization in precision education. After reviewing the current literature, the researcher identified and categorized these prerequisites into four key areas (Kuch et al., 2020; Williamson, 2019a; Lu et al., 2018; Sabatello, 2018; Cesarini & Visscher, 2017):

1. Involve students and pertinent stakeholders, ranging from parents and students to healthcare professionals, educators, and policymakers.
2. Research priorities and evidence generation.
3. Application of effective precision education practices.
4. Datafication, Ownership, privacy, and sharing of data

1. Engage Students and Stakeholders: Putting Students at the Core of Precision Education Priorities

Students are the main pillar of genomics-based precision education, as their genetic and personal information is the essential component of precision education and the basic indicators for identifying their needs. Students' confidence that their data will be used effectively and ethically is of great importance. Therefore, attention must be given to having enhanced transparency in genetic and personal information systems and building channels of communication with the relevant stakeholders. Therefore, the following future prerequisites should be considered (Sabatello, 2018):

e. Building confidence in genomics-based precision among educational practitioners and stakeholders.

f. Acceptance of Genomics-based precision education by academics, students, and stakeholders.

g. Determining which institutional changes come with Genomics-based precision education.

h. Explaining the rationale and importance of adopting Genomics-based precision education to the stakeholders.

2. Evidence Generation and Research Priorities

Imminent scientific investigations into the genetic aspects of educational achievement and its precursors, such as intelligence, personality dimensions, dyslexia, and attention challenges, combined with the discovery of genetic elements influencing educational outcomes, may elucidate the intricate ways in which genes contribute to shaping learning success. This newfound awareness could potentially equip educators with the tools to tailor proactive interventions informed by genetic data, addressing the unique needs of individual students (Cesarini & Visscher, 2017).

It is imperative to focus on cost-effectiveness research, aiming to identify the most urgent learning disabilities within particular student demographics. Following this, it becomes vital to precisely determine which intervention strategies achieve their goals effectively when aligned with specific genetic data. Educators should strive to understand the factors contributing to improved outcomes and the implementation of more effective educational methodologies (Williamson, 2019a).

3. Application of Effective Precision Educational Practices

a. To fully realize the potential of genomicization of precision education, educational practitioners should first develop new precision education practices. Before utilizing a student's genetic information, it is crucial to undertake innovative research to determine the effectiveness of interventions for specific individuals, understand the mechanisms of their efficacy, and develop robust preventive and intervention strategies tailored to the distinct requirements of each learner. This approach should be intricately informed by the dynamic interplay between educational environments and the unique genetic profiles of learners (Williamson, 2019a).

b. Technology information and other analytical tools, such as learning analytics and adaptive learning software, should be employed to support optimal decision-making about the appropriate interventions (Williamson, 2019a).

4. Datafication, Ownership, Privacy, and Sharing of Data

a. Precision education faces not only a wealth of information but also the rapid integration of diverse practices within its realm. Those involved in education need effortless access to reliable information and guidelines in this dynamic landscape. In this regard, learning analytics and educational big data can be applied as a robust conceptual framework to promote the analysis and prediction of students' performance, providing appropriate and timely interventions based on student learning profiles (Williamson, 2019a; Lu et al., 2018). Education, among other domains, has been transformed by datafication, which involves converting various aspects of education into quantifiable digital data that can be analyzed to inform policy-making (Kuch, Kearnes, & Gulson, 2020).

b. Thus, the materialization of precision education relies on an advanced data analytics platform. This system is anticipated to aid educators in formulating precise learning strategies and appraising the progress of students through these strategies.

c. To optimally use students' genetic information to develop suitable interventions, the availability of comprehensive family histories will be a must. Despite having access to the complete genetic data of a student, it remains essential to decipher this information within the frameworks of both biological and environmental contexts in which the genomes manifest.

d. Developing an ethical framework that addresses potentially related risks and concerns of providing personal genetic information and privacy protection mechanisms is crucial.

e. Genomics-based-precision education information should be provided for students via their electronic portals connected to their electronic learning records. Cultural contexts should be taken into account, meaning that the records and materials must be designed at the level of different cultures (Sabatello, 2018).

f. Develop guides that incorporate different levels of initial use of Genomics-based precision, controls, procedures, and conditions for continuous collection of data on the efficacy of Genomics-based precision education (Sabatello, 2018). Establish standards for shared data elements to record information in electronic records (Sabatello, 2018).

3. Methodology and Procedures

In the quest to comprehend the fundamental elements necessary for the successful integration of precision education based on genomics, this exploratory descriptive research utilized a questionnaire as its principal instrument for data collection. The aim was to recognize and prioritize the forthcoming requirements vital for the triumphant implementation of this educational paradigm. The questionnaire, meticulously devised by the researcher, took shape after an exhaustive examination of relevant literature (Kuch et al., 2020; Williamson, 2019a; Lu et al., 2018; Sabatello, 2018; Cesarini & Visscher, 2017).

The questionnaire consisted of two sections: the first section included (22) items, distributed in four domains: The domain of engaging students and the relevant stakeholders included (4 items), the domain of research priorities and evidence generation included (6 items), the domain of application included (3 items), and the domain of datafication, ownership, privacy and sharing of data embraced (9 items). The questionnaire utilized a Likert-type scale with five points (1 - Very low importance, 2 - Low importance, 3 - Moderate importance, 4 - High importance, and 5 - Very high importance) to assess the relative importance of identified future prerequisites and rank them accordingly. The second segment comprised statements related to pertinent demographic information required from potential participants.

To measure internal consistency, the questionnaire's overall Cronbach's alpha coefficient (α) was calculated, indicating values ranging from 0.84 to 0.91 across items and domains. The overall stability, depicted by a coefficient of 0.89 (as outlined in Table 1), is notably high, effectively meeting the study's objectives. Face validity was ensured through a thorough review by seven academic experts, leading to modifications based on their feedback. A pilot test with 11 experienced teaching staff further guided adjustments to improve the questionnaire's reliability.

Table 1: Cronbach's alpha values for the questionnaire and its respective domain

Total Stability		Engage students and the relevant stakeholders		Evidence generation		Application		Ownership, privacy, and sharing of data	
		Stability Coefficient	Number of items	Stability Coefficient	Number of items	Stability Coefficient	Number of items	Stability Coefficient	Number of items
0.89	22	0.91	4	0.90	6	0.84	3	0.84	9

3.1. Target Participants

To ensure a rich and multifaceted representation of the Egyptian College of Education faculty, this study employed a rigorous, two-pronged selection approach. Firstly, geographical and institutional diversity were considered. Participants hailed from five geographically distinct universities, situated across urban and rural settings: Ain Shams (Cairo), Tanta (Lower Egypt), Assiut (Upper Egypt), Zagazig (Delta), and Helwan (Greater Cairo). Furthermore, colleges represented a spectrum of sizes (large, medium, and small), reflecting diverse institutional contexts and resources.

Secondly, expertise and perspective diversity were crucial. The 169 participants were carefully chosen not only for their expertise in specific fields (Education, Science, and Literature) but also for their ability to offer varied academic backgrounds and viewpoints. This deliberate selection strategy aimed to capture the multifaceted experiences and opinions within Egyptian colleges of education, ultimately strengthening the depth and breadth of the study's findings.

Before participation, all individuals received information about the questionnaire's purpose. To minimize response bias, including social desirability bias, the author implemented measures ensuring anonymity and confidentiality during the data collection process.

Table 2: Profile of participants

Study variables	Variable levels	Frequency (f)	Percentage (%)
Gender	Male	79	46. 745
	Female	90	53.254
	Total	**169**	**100**
Academic Rank	Professor	57	33. 728
	Associate Professor	67	39.645
	lecturer	45	26.627
	Total	169	100
Specialized domain	Educational	63	37. 278
	Scientific	49	28.994
	Literary	57	33.728
	Total	**169**	**100**

3.2. Ethical Considerations

This study did not involve any intervention, sensitive personal data, or vulnerable populations. Participation in the questionnaire was entirely voluntary, and all respondents were informed of the research's purpose. Anonymity and confidentiality were strictly maintained, and no identifiable personal information was collected. The data was used solely for academic research purposes, in accordance with established ethical research practices.

3.3. Statistical Analysis

The processing of data involved using the SPSS Analysis program, version 23, to conduct a descriptive analysis of the gathered information. The mean score served as a metric to evaluate respondents' levels of agreement regarding the future prerequisites for the effective implementation of genomics-based precision education. The interpretation criteria are outlined in Table 3:

M = 1.00-1.50: Very low importance

M = 1.50-2.50: Low importance

M = 2.50-3.50: Moderate importance

M = 3.50-4.50: High importance

M = 4.50-5.00: Very high importance

The statistical analysis also included the application of Cronbach's alpha formula, the Z-test, and the Pearson correlation coefficient.

4. Results and Discussion

The questionnaire was divided into two main sections: The first section included four domains of future prerequisites for the successful implementation of genomics-based precision education: engaging students and relevant stakeholders, evidence generation for precision education application, and ownership, privacy, and sharing of data. The investigator employed closed-ended Likert scale statements (ranging from "Very low importance" to "Very high importance") for participant responses. The second part was dedicated to gathering demographic data from participants. The principal findings are outlined as follows:

Table 3: Categorization of mean scores into respective weight categories

Degree of importance of the strategic prerequisite	Weight	Corresponding Relative Weight
Very high importance	5	4.5 or More
High importance	4	3.5 – Below 4.5
Moderate importance	3	2.5 – Below 3.5
Low importance	2	1.5 – Below 2.5
Very low importance	1	Below 1.5

Q2. What is the relative importance of future prerequisites for the successful implementation of Genomics-based precision education from the perspectives of academic staff at five Egyptian colleges of education, according to the variable of gender (males, females), academic rank (professor, associate professor, and lecturer), and specialized domain (Educational, Scientific, and Literary)?

To answer this question, calculations were performed for means, relative importance, and item rankings, as detailed in Table 4. The interpretation of results relied on the means and relative importance values, as outlined in Table 3.

Table 4: Mean score of the academic staff's points of view on the future prerequisites according to the variable of gender

	Items	Female				Male			
		M	SD	RI	R	M	SD	RI	R
	First domain: engage students and the relevant stakeholders								
1 -1	Building confidence in Genomics-based precision among educational practitioners and stakeholders.	4.811	0.394	0.962	1	4.848	0.361	0.970	2
1 -2	Acceptance of Genomics-based precision education by academics, students, and stakeholders.	4.778	0.418	0.956	2	4.939	0.361	0.988	1
1 -3	Determining which institutional changes come with Genomics-based-precision education.	4.700	0.461	0.940	3	4.608	0.564	0.922	4
1 -4	Explaining the rationale and importance of adopting Genomics-based precision education to the stakeholders.	4.633	0.570	0.927	4	4.785	0.414	0.957	3
	Second domain: research priorities and evidence generation								
2 -1	Identifying genes influencing students' achievement in core school subjects, intelligence, self-efficacy, behavioral problems, well-being, and perceptions of the school environment.	4.467	0.706	0.876	5	4.418	0.744	0.884	6
2 -2	Identifying which competencies staff and students need for teaching and learning in Genomics-based-precision education environments.	4.356	0.739	0.876	6	4.406	0.725	0.881	7
2 -3	Identifying which prevention and intervention strategies will achieve their goals when they are implemented based on certain genetic data.	4.356	0.739	0.871	7	4.532	0.637	0.906	5

Items		Female				Male			
		M	SD	RI	R	M	SD	RI	R
2 -4	How to tailor prevention and intervention practices to individual learners based on the best available evidence.	4.322	0.747	0.864	8	4.392	0.775	0.878	8.5
2 -5	How to align educational environments with genetic differences to maximize learners' potential.	4.289	0.753	0.858	9	4.392	0.775	0.878	8.5
2 -6	Conducting cost-effectiveness research to justify investments of personnel and technological resources for applying Genomics-based precision education (i.e., return on investment).	4.244	0.769	0.849	10	4.342	0.766	0.766	10
Third domain: application									
3 -1	Availability of suitable prevention and intervention practices that match each learner's needs based on the interaction between educational environments and students' distinctive genetic profiles.	4.144	0.801	0.829	11.5	4.266	0.858	0.853	11
3 -2	Developing a robust, practical framework to guide the adaptation of educational processes in terms of students' genetic profiles.	4.144	0.801	0.829	11.5	4.253	0.869	0.851	12
3 -3	Developing educational curricula to maximize children's different genetic potentials.	4.089	0.857	0.818	13	4.228	0.847	0.846	13.5
Fourth domain: datafication, ownership, privacy, and sharing of data									
4 -1	Availability of every student's genetic makeup.	4.089	0.802	0.818	14	4.127	0.882	0.825	15
4 -2	Availability of students' comprehensive family histories to interpret the information in terms of the biological and environmental contexts in which the students' genomes are expressed.	4.078	0.851	0.816	15	4.126	0.882	0.825	16
4 -3	Developing a robust conceptual framework to analyze and predict students' performance in terms of his/her distinctive genetic profile.	4.056	0.826	0.811	16	4.228	0.876	0.846	13.5

Items		Female				Male			
		M	SD	RI	R	M	SD	RI	R
4 -4	Adopting datafication to transform the different features of education into quantifiable digital data that can be exploited through analytics to inform policy-making.	4.033	0.827	0.807	17	4.114	0.891	0.823	17

Note: M Mean, SD Standard Deviation, RI Relative Importance, Ranking

Table 4 presents the mean scores, standard deviations, relative importance (RI), and ranking (R) of academic staff perspectives on these prerequisites, categorized by domain and gender. Generally, both genders agree on the importance of most prerequisites, emphasizing building confidence and gaining stakeholder acceptance (1st domain, items 1-1 & 1-2) and identifying genes influencing student characteristics (2nd domain, item 2-1).

Slight variations emerge, with males scoring slightly higher on the importance of most items compared to females. This could be attributed to various factors, such as differing experiences, risk-taking preferences, or technological comfort levels, as mentioned by Asbury (2015). Females score slightly higher on the importance of explaining the rationale for adopting genomics (1st domain, item 1-4) and considering cultural contexts (4th domain, item 4-8). This aligns with Thomas et al. (2015), who highlight the potential for diverse perspectives on the ethical and social implications of genomics.

Domain-Specific Analysis:

- Domain 1 (Engaging stakeholders): Both genders agree on the crucial role of public engagement, as highlighted by Strianese et al. (2020).

Domain 2 (Research priorities): Identifying genes and understanding the biological aspects are seen as important, but cautiously so, reflecting concerns about over-reliance on genetics as mentioned by Sabatello (2018).

- Domain 3 (Application): Both genders prioritize practical considerations like the availability of interventions and frameworks for effective implementation.
- Domain 4 (Data considerations): While both acknowledge the importance of data, they assign slightly lower importance to areas like data analysis for policy-making and data sharing, highlighting the need for careful attention to ethical considerations as emphasized by Rahimzadeh et al. (2020).

Balancing Priorities and Ethical Considerations:

While all prerequisites hold some degree of importance, as indicated by the mean scores exceeding 3.5 for all items, it is crucial to acknowledge the ethical complexities surrounding privacy, informed consent, and potential discrimination, as raised by Rahimzadeh et al. (2020). Integrating these considerations necessitates careful planning, public dialogue (Thomas et al., 2015), and ongoing attention to balancing potential benefits with ethical safeguards. Additionally, proposals for advancing genomic medicine emphasize the importance of education (Nisselle et al., 2023), further highlighting the need for responsible integration that considers not only the potential benefits but also the ethical challenges and diverse stakeholder perspectives.

Table 5: Mean score of the academic staff's points of view on the future prerequisites according to the variable of academic rank

Items	Professor				Associate Professor				Lecturer			
	M	SD	RI	R	M	SD	RI	R	M	SD	RI	R
First domain: engage students and the relevant stakeholders												
1-1[1]	4.896	0.309	0.979	1	4.789	0.411	0.958	1	4.778	0.420	0.956	1
1-2	4.851	0.359	0.970	2	4.754	0.434	0.951	2	4.711	0.458	0.942	2
1-3	4.776	0.420	0.955	3	4.649	0.481	0.930	3	4.644	0.484	0.929	3
1-4	4.657	0.592	0.931	4	4.614	0.559	0.923	4	4.578	0.543	0.916	4
Second domain: research priorities and evidence generation												
2-1	4.642	0.620	0.928	5	4.421	0.755	0.884	5	4.489	0.661	0.898	5
2-2	4.478	0.746	0.896	6	4.368	0.747	0.874	8	4.267	0.751	0.853	8
2-3	4.403	0.780	0.881	7	4.386	0.750	0.877	6	4.444	0.624	0.889	6
2-4	4.373	0.775	0.875	8	4.386	0.750	0.877	7	4.356	0.645	0.871	7
2-5	4.358	0.773	0.872	9	4.298	0.801	0.860	9	4.267	0.654	0.853	9
2-6	4.284	0.813	0.857	10	4.228	0.756	0.846	10	4.222	0.704	0.844	10

Table 5 presents the mean scores (M), standard deviations (SD), relative importance (RI), and ranking (R) of the academic staff's perspectives on future prerequisites for integrating genomics into educational practices, categorized by academic rank (Professors, Associate Professors, Lecturers). This analysis offers insights into potential variations in viewpoints based on experience and career stage. While there is general agreement across ranks on the importance of most prerequisites, some subtle differences emerge. Notably, Professors consistently assign slightly higher scores than Associate Professors and Lecturers. This could be attributed to factors like:

- Greater experience: Professors might have a broader understanding of the complexities involved in educational change and the potential of genomics.
- Leadership roles: Professors often hold leadership positions and might focus more on strategic planning and long-term considerations.

Domain-Specific Analysis

Domain 1 (Engaging stakeholders): All ranks consider building confidence and gaining stakeholder acceptance (items 1-1 & 1-2) highly important, underlining the crucial role of effective communication

1 The author used the codes of the items to simplify the table.

and collaboration. Interestingly, while all groups rank determining necessary institutional changes (items 1-3) as moderately important, Professors assign a slightly higher score than the other two ranks. This suggests a potential emphasis on long-term planning and adapting institutional structures to accommodate this educational shift.

Domain 2 (Research priorities and evidence generation): Identifying genes influencing student characteristics (item 2-1) is consistently ranked as important across all ranks. However, Professors place slightly higher significance on items related to identifying effective prevention and intervention strategies (items 2-4) and aligning educational environments with genetic differences (items 2-6). This could reflect a focus on the practical applications of genomics in educational settings and ensuring its effectiveness in improving learning outcomes.

This alignment with Whitley et al. (2020) underscores the broader recognition within the education community of the need to develop a comprehensive framework for integrating genomics into educational practices. This framework should acknowledge the diverse perspectives of stakeholders, including those highlighted by the variations in viewpoints across academic ranks, and address the ethical considerations raised by Rahimzadeh et al. (2020).

Table 6: Mean score of the academic staff's points of view on the future prerequisites according to the variable of specialized domain

Items	Educational				Scientific				Literary			
	M	SD	RI	R	M	SD	RI	R	M	SD	RI	R
First domain: engage students and the relevant stakeholders												
1-1	4.905	0.296	0.981	1	4.592	0.497	0.918	3	4.649	0.481	0.930	3
1-2	4.889	0.317	0.978	2	4.755	0.434	0.951	1	0.398	0.961	4.807	1
1-3	4.825	0.388	0.965	3	4.694	0.466	0.939	2	0.444	0.947	4.737	2
1-4	4.698	0.586	0.940	4	4.592	0.537	0.918	4	4.561	0.567	0.912	4
Second domain: research priorities and evidence generation												
2-1	4.603	0.685	0.921	5	4.429	0.677	0.886	5	4.491	0.601	0.898	5
2-2	4.556	0.736	0.911	6	4.388	0.702	0.878	8	4.281	0.796	0.856	8
2-3	4.381	0.771	0.876	7	4.408	0.674	0.882	6	4.351	0.767	0.870	6
2-4	4.365	0.789	0.873	8	4.408	0.674	0.882	7	4.298	0.755	0.860	7
2-5	4.349	0.7845	0.870	9	4.347	0.663	0.869	9	4.281	0.774	0.856	9
2-6	4.317	0.779	0.863	10	4.306	0.742	0.861	10	4.175	0.759	0.835	10
Third domain: application												
3-1	4.286	0.811	0.857	11	4.265	0.785	0.853	11	4.105	0.859	0.821	11

Items	Educational				Scientific				Literary			
	M	SD	RI	R	M	SD	RI	R	M	SD	RI	R
3 -2	4.222	0.869	0.844	12	4.265	0.758	0.853	12	4.035	0.886	0.807	12
3 -3	4.222	0.870	0.844	13	4.265	0.730	0.853	13	4.035	0.944	0.807	13
Fourth domain: datafication, ownership, privacy, and sharing of data												
4 -1	4.190	0.8773	0.838	14	4.265	0.730	0.853	14	3.965	0.906	0.793	14
4 -2	4.175	0.9077	0.835	16	4.224	0.743	0.845	16	3.877	0.847	0.775	16
4 -3	4.175	0.9077	0.835	15	4.224	0.743	0.845	15	3.930	0.821	0.786	15
4 -4	4.143	0.9133	0.829	17	4.224	0.743	0.845	17	3.860	0.854	0.772	17
4 -5	4.079	0.9034	0.816	18	4.163	0.746	0.833	18	3.702	0.778	0.740	18
4 -6	3.968	0.8793	0.794	19	4.000	0.764	0.800	19	3.632	0.747	0.726	19
4 -7	3.937	0.8776	0.787	20	3.939	0.747	0.788	21	3.421	0.680	0.684	21
4 -8	3.857	0.8397	0.771	21	4.000	0.764	0.800	20	3.509	0.710	0.702	20
4 -9	3.825	0.8336	0.765	22	3.898	0.770	0.780	22	3.404	0.678	0.681	22

Table 6 presents valuable insights into the perspectives of academic staff from various specialized domains regarding the future prerequisites for integrating genomics into educational practices. While there is a general trend of agreement on the importance of most prerequisites, some intriguing variations emerge based on the staff’s area of specialization.

Domain-Specific Variations

1. Engaging Stakeholders: Across all domains, building confidence and gaining stakeholder acceptance (items 1-1 & 1-2) rank as highly important, emphasizing the crucial role of effective communication and collaboration. Interestingly, “Educational” and “Literary” staff assign slightly higher scores to explaining the rationale for adopting genomics-based precision education (items 1-4), likely reflecting their understanding of the need to address potential concerns and garner support within their respective communities.
2. Research Priorities and Evidence Generation: While all groups view identifying genes influencing student characteristics (item 2-1) as important, “Educational” and “Scientific” staff prioritize it slightly higher than “Literary” staff. This could be attributed to the inherent focus on student learning and development in the first two domains, while the “Literary” domain might place greater emphasis on broader socio-cultural implications of integrating genomics.
3. Application: Notably, all groups view the availability of suitable interventions and a practical framework (items 3-1 and 3-2) as crucial. This suggests a shared recognition of the need for actionable strategies and a structured approach to utilize the potential of genomics effectively in educational settings.

4. Datafication, Ownership, Privacy, and Sharing of Data: Across all domains, developing data privacy mechanisms and considering cultural contexts (items 4-7 and 4-8) receive relatively lower scores compared to other prerequisites. This finding aligns with Rahimzadeh et al. (2020), who highlight the ethical concerns surrounding data privacy and cultural sensitivity in utilizing genetic information. While the "Literary" staff assigns slightly higher importance to these considerations, there is a clear call for further exploration and comprehensive ethical frameworks to address these concerns effectively.
5. ***Ethical considerations:*** Building on the finding that data privacy and cultural contexts received relatively lower prioritization (items 4-7 and 4-8), it is crucial to establish robust ethical frameworks. As highlighted by Thomas et al. (2015) and Rahimzadeh et al. (2020), these frameworks must ensure transparent and systematic approaches to data privacy, informed consent, and potential discrimination, supported by ongoing public dialogue.

Q3. Is there a statistical significance in the variations of participants' responses corresponding to their demographic characteristics?

To answer this question, the relative importance of each domain was calculated, and then, *Z*-test was applied as shown in Tables (7, 8, and 9).

Table 7: The relative importance and z-values of the respondents according to the gender variable (males, females)

Domain	Relative Importance		Z Score	
	Female (90)	Male (79)	Z Value	P-Value
1. Involve students and pertinent stakeholders, spanning parents, students, health professionals, educators, and policymakers.	0.885	0.560	0.707	1.96
2. Research priorities and evidence generation.	0.838	0.950	0.402	
3. Application of effective precision education practices.	0.816	0.916	0.476	
4. Datafication, Ownership, privacy, and sharing of data	0.791	0.845	0.348	

The critical Z-score value at a significance level of 0.05 is 1.96.

Table 7 presents findings regarding potential gender-based differences in perspectives on integrating genomics into educational practices. While the overall relative importance scores are high across all domains for both genders, the z-scores suggest potential areas of divergence. This warrants further exploration through the lens of academic and professional expertise.

Domain 1: Stakeholder Involvement

Both genders assign high importance to involving various stakeholders (0.885 for females, 0.707 for males). However, the z-score of 1.96 indicates a statistically significant difference at the 0.05 level. This potentially suggests that females might place a stronger emphasis on comprehensive stakeholder engagement compared to males. This aligns with research by Thomas et al. (2015), who highlight the importance of considering diverse viewpoints in educational decision-making.

Domains 2 and 3: Research and Application

The z-scores for both Domain 2 (Research Priorities) and Domain 3 (Application) fall below the critical value, indicating no statistically significant differences. This suggests relative alignment between genders regarding the importance of research and its practical application in integrating genomics into education. Both genders likely recognize the need for a strong foundation in research evidence to guide the development and implementation of effective precision education practices (Cook et al., 2018).

Domain 4: Data Considerations

The z-score (0.348) for Domain 4 (Datafication) falls below the critical value, suggesting no significant difference between genders. However, it is crucial to acknowledge that despite both genders assigning high importance (0.791 for females, 0.845 for males), the scores are still slightly lower compared to other domains. This highlights the persistent need for ongoing dialogue and awareness-raising regarding ethical considerations surrounding data ownership, privacy, and sharing in the context of educational genomics, as emphasized by Rahimzadeh et al. (2020). Open communication and collaboration among educators, policymakers, and the public are essential for navigating these complexities and ensuring responsible data practices.

Table 8: The relative importance and z-values of the respondents according to the academic rank variable (professor, associate professor, and lecturer)

Domain	Relative Importance			Z Score	
	Professor (57)	Associate Professor (67)	Lecturer (45)	Z Value	P-Value
1. Involve students and pertinent stakeholders, spanning parents, students, health professionals, educators, and policymakers.	0.909	0.986	0.982	0.632	1.96
2. Research priorities and evidence generation.	0.843	0.933	0.954	0.802	
3. Application of effective precision education practices.	0.821	0.917	0.817	0.457	
4. Datafication, Ownership, privacy, and sharing of data	0.792	0.877	0.877	0.708	

The critical Z-score value at a significance level of 0.05 is 1.96.

Table 8 indicates that while all ranks assigned high relative importance scores across most domains, subtle variations emerged.

Domain 1: Stakeholder Involvement

Despite all ranks prioritizing stakeholder involvement (0.909 for Professors, 0.986 for Associate Professors, and 0.982 for Lecturers), the z-score (0.632) falls below the critical value (1.96), indicating no statistically significant difference. This aligns with the emphasis on inclusivity and diverse viewpoints highlighted by Thomas et al. (2015). All academic ranks appear to agree on the importance of comprehensive stakeholder engagement, encompassing perspectives from students, parents, educators, and policymakers.

Domains 2 & 3: Research & Application

Similar to Domain 1, the z-scores for both Domain 2 (Research priorities) and Domain 3 (Application) fall below the critical value, suggesting no significant differences between ranks. This implies relative consensus across ranks on the importance of research-based evidence to guide the development and implementation of effective precision education practices, as advocated by Cook et al. (2018). All ranks likely recognize the need for a solid foundation in research to ensure responsible adoption of genomics in educational settings. Asbury and Plomin (2013) further emphasize the potential benefits of such research for educational interventions.

Domain 4: Data Considerations

The z-score (0.708) for Domain 4 (Datafication) falls closer to the critical value compared to other domains, suggesting a potential trend worth exploring further. While all ranks acknowledge the importance of data considerations, Professors assigned slightly higher significance (0.941) compared to Associate Professors (0.900) and Lecturers (0.872). This potential difference might stem from Professors' broader responsibilities related to institutional policies and ethical oversight, as highlighted by Williamson (2019a). Further research investigating the rationale behind these potential variations could provide valuable insights, as suggested by Asbury (2015).

Table 9: The relative importance and z-values of the respondents according to specialized domain variable (educational, scientific, and literary)

Domain	Relative Importance			Z Score	
	Educational (63)	Scientific (49)	Literary (57)	Z Value	P-Value
1. Involve students and pertinent stakeholders, spanning parents, students, health professionals, educators, and policymakers.	0.895	0.983	0.982	0.705	1.96
2. Research priorities and evidence generation.	0.898	0.953	0.955	0.802	
3. Application of effective precision education practices.	0.876	0.917	0.917	0.805	
4. Datafication, Ownership, privacy, and sharing of data.	0.851	0.877	0.877	0.708	

The critical Z-score value at a significance level of 0.05 is 1.96.

Table 9 shows that all groups assign high relative importance (above 0.85) to stakeholder involvement (Domain 1), research priorities (Domain 2), and application of precision education practices (Domain 3). This aligns with the emphasis on collaborative, evidence-based, and practical approaches advocated by Cook et al. (2018) and Thomas et al. (2015).

Data Considerations (Domain 4): While all groups acknowledge the importance of data (scores above 0.85), the z-score (0.708) suggests no statistically significant difference. However, there might be a trend worth exploring further, as is evident in slightly higher relative importance scores assigned by the scientific and literary groups compared to the educational group. This aligns with the increasing focus on data privacy and ethical considerations in scientific and literary domains, as highlighted by Rahimzadeh et al. (2020) and Whitley et al. (2020).

Domain-Specific Insights:

Educational Domain: The educational group scores relatively lower on data considerations, potentially reflecting their primary focus on pedagogical practices and student well-being. This aligns with the concerns raised by Sabatello (2018) regarding potential misapplications of genetics within education.

Scientific Domain: The scientific group assigns slightly higher importance to data-related considerations, likely due to their expertise and awareness of the complexities surrounding data security, privacy, and ethical implications, as emphasized by Strianese et al. (2020).

Literary Domain: The literary group's relatively higher score on data considerations might stem from their understanding of ethical concerns surrounding personal information and narratives, echoing the arguments presented by Baron-Cohen et al. (2014) regarding the potential societal implications of genetic research.

5. Conclusion

This research explores the transformative potential of Educational Genomics to shape the future of precision education. The study identified key prerequisites for its successful implementation from an educational perspective, finding no significant differences in their importance across various demographic groups, suggesting a consensus on their critical role.

These findings reveal the transformative potential of Educational Genomics. By providing insights into learning and individual differences, it can drive personalized learning strategies, optimize interventions, and even predict and prevent challenges. However, responsible implementation necessitates careful consideration of ethical, accessibility, and societal issues. Collaboration across diverse fields, including educators, researchers, and policymakers, is crucial to ensure equitable access and responsible use of genetic information in education.

The future of education might involve analyzing student DNA for personalized learning, similar to advancements in personalized medicine. This necessitates a shift towards personalized educational methodologies tailored to individual genetic profiles. Future research in Educational Genomics should focus on optimizing learning experiences for all learners, including understanding individual differences, predicting potential challenges, and developing effective interventions.

Building trust is crucial for successful implementation. Stakeholders need to trust the technology, the process, and each other to enable meaningful data sharing and positive outcomes. Educators must also prepare for the genomics revolution by understanding its potential, ethical implications, and legal considerations. This proactive approach will ensure responsible integration and maximize the benefits for learners.

The identified framework offers a valuable roadmap for further research and development in Educational Genomics, ultimately unlocking the potential for personalized learning and positive outcomes for all students.

6. Recommendations

This research highlighted the promising potential of genomics to transform educational practice. However, harnessing this potential necessitates careful consideration of ethical, logistical, and pedagogical factors. To this end, several recommendations are proposed:

Firstly, evidence-based policy development is essential. Collaborative efforts among educators, policymakers, and researchers are crucial for creating ethical policies for using genomics in education. These policies should address critical issues such as data privacy, informed consent, and responsible use of genetic information.

Secondly, prioritizing teacher training and development is vital. Educators need the knowledge, skills, and ethical grounding to effectively integrate genomics into their practice. This requires the establishment of comprehensive training programs, workshops, and ongoing professional development opportunities.

Thirdly, fostering international collaboration and knowledge sharing is key. A global network of researchers, educators, and policymakers can facilitate knowledge exchange, address common challenges, and promote unified approaches to genomics-based precision education. This network can share best practices, develop collaborative research projects, and advocate for international policy harmonization.

Lastly, advancing research on educational applications is imperative. Further research is needed to investigate how genomics can be used to design personalized learning strategies, develop curricula, and inform assessment practices. This may involve pilot studies, randomized controlled trials, and longitudinal research to assess the effectiveness of genomics-based interventions in real-world educational settings.

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Final declarations:

- The authors declare that they got the required voluntary human participants consent to participate in the study as well as the necessary institutional approvals.
- The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

تصريحات ختامية:

- يصرح المؤلف/ المؤلفون بالحصول على موافقة الأشخاص المتطوعين للمشاركة في الدراسة وعلى الموافقات المؤسسية اللازمة.
- تتوفر البيانات الناتجة و/ أو المحلَّلة المتصلة بهذه الدراسة من المؤلف المراسل عند الطلب.