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The Science of Science Education: Zoel García de Galdeano, Mathematics Instruction, and the Progress of Spain

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In 1891, Zoel García de Galdeano, a mathematics professor at the Universidad de Zaragoza, embarked on a quixotic enterprise. Seeking to make the most important advances in mathematics available in Spain, he founded the first specialized journal of this field in the country, *El Progreso Matemático*, serving simultaneously as its editor, contributor, and manager. The journal also provided a space to criticize the backwardness of education and the absence of local scientific developments on the Iberian Peninsula. Three comprehensive essays authored by García de Galdeano and published in the journal from 1893 to 1894, and from 1899 to 1900, are emblematic of this editorial stance. The pieces, entitled "Estudios sobre la enseñanza y el organismo de la ciencia matemática," "La enseñanza de la ciencia matemática en la universidad," and "La matemática y su enseñanza," invoke mathematics instruction as a paradigm to develop and to implement an entirely new structure of the educational system. In García de Galdeano's view, theory and practice—usually treated as unconnected instances of the educational body—should be correlated but independent components of higher education, much like pure and applied knowledge should constitute the core of science. An unbalanced approach to education, however, had dramatically limited the possibilities for autonomous scientific and technical development and, as a consequence, the successful transition of the country into an industrial society and its consolidation as a modern nation. García de Galdeano believed in the broad concept of the university, a space where education provided a compendium of universal knowledge and fostered an understanding of both the sensorial and the conceptual worlds. In this context, the teaching of mathematics was instrumental in supplying, on the one hand, the tools to create an abstract representation of natural phenomena, and, on the other, the concepts to understand the highest notions of philosophy.

As García de Galdeano would assert in the essays discussed here, the particular approach to education that prevailed in the country was a direct consequence of the State's refusal to acknowledge the country's condition of backwardness and economic disadvantage in relation to other European nations, and of the inadequate scientific curricula at the higher-education level to deal appropriately with these social problems. If one accepts the

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idea that science should comprise both theoretical and practical matters, then it follows that a modern country would need to strongly promote both fronts in order to attain consistent material progress. A critical understanding of the philosophical foundations of science, and not only a notion of its utility in the mechanisms of industry, was therefore the key element to develop what the author called "la ciencia propia" ("La matemática" 2.8: 53), as it would provide students with the long needed aptitude for investigation.[1] As I show, by advancing these ideas on education *El Progreso Matemático* became a privileged arena for social criticism, political discussion, and cultural exchange, contributing to the diagnosis and treatment of the country's problems. By emphasizing the importance of developing a national scientific tradition, this effort positioned García de Galdeano's ideas in the context of Regenerationism, where his proposal joined forces with that of other scientists and intellectuals of his time.[2]

Although historians of science have studied the work of García de Galdeano, both in his journal and in his extensive scholarship, cultural critics have not yet considered *El Progreso* as one of the most important attempts to establish the foundations of a national scientific tradition based on education, in the way they have, for example, with Santiago Ramón y Cajal's non-specialized writings.[3] The emphasis that García de Galdeano's essays place on the need to develop an adequate educational apparatus called attention to the impossibility of forging a modern nation without the material and intellectual resources that science provides.[4] Considering the author's position as a cultural entrepreneur, in what follows I discuss his use of a scientific publication to intervene in cultural and political matters. For him, education's ability to foster the distinctive creativity and ingenuity of the Spanish intellect was pivotal for the consolidation of a national science. The way García de Galdeano made his case for restructuring higher education not only enlightens our understanding of the place of science, education, and mathematics in *fin-de-siglo* Spain, but also shows the role of scientific instruction in the reconceptualization of what was understood as national.

García de Galdeano and the Spain of *El Progreso Matemático*

The last decade of the nineteenth century in Spain was a period of political and social renovation in which cultural actors from all social classes were continuously reworking the symbolic frameworks governing everyday life.[5] In this context, García de Galdeano embodied what Itamar Even-Zohar defines as a "cultural entrepreneur" (194), an active public figure with the ability to intervene in the political and cultural fronts of Spanish social life. Through his journal, the author actively mediated in the reevaluation of the past, the diagnosis of the present, and the prognosis of the future. His role as a social critic was akin to Said's vision of an intellectual: a person who articulates a concept, an idea, even an attitude or a philosophical perspective about society, and makes it accessible to a specific audience (11). As an intellectual and a cultural entrepreneur, García de Galdeano used *El Progreso*'s periodicity to address national problems as they were occurring. This emphasis on the import of print media is not surprising if we consider the author's affiliation with Krausism. One of the advances achieved during the revolutionary period was the freedom of the press, which Krausists exploited to actively participate in what José Sala Catalá has defined as the first national movement of scientific popularization (43). For Krausists, the circulation of knowledge was essential in education. *El Progreso*

aligned with this principle and, as its list of subscribers attests, tried to capture the attention of an important number of educators and politicians.[6] Conscious of this readership, the author sought to make higher education—and the role of science and mathematics in it—the center of the journal's editorial line.

While the last part of the century was a decisive period for the consolidation of science in countries like France, Germany, and England, similar achievements in Spain remained scant. The development of national scientific cultures around Europe was in part the result of strong and well-established traditions of intellectual inquiry, an attribute that Spain, according to some contemporary thinkers, had not yet developed.[7] With mathematics playing a central role in this process, new ideas in fields such as logic, algebra, and geometry had to be imported. Spanish intellectuals and scientists thus engaged with new and intricate concepts, some of which altered their conceptualizations of reality and their understanding of society. In other countries, the discovery of non-Euclidian geometries, for example, had changed the mechanisms of representation that art, literature, and music used to capture the social, economic, and political complexities of the time. In numerous ways, and as Andrea Henderson contends, the cultural significance of these epistemological transformations was that the public ended up questioning the validity of established modes of representation (457).[8]

This cognitive revolution also impacted social analysis, politics, and, particularly, education. *El Progreso* incorporated some of these advanced notions into its proposed model of teaching and curricular design. For example, using Cantor's theory of sets, a revolutionary advancement in logic, García de Galdeano explained how abstraction was key in understanding and teaching concrete phenomena:

> La inteligencia se apodera de un sistema abstracto, correspondiente a un sistema concreto; y nos hallamos en un primer caso de correspondencia, que juntamente con muchos otros que obtendremos, permite definir la matemática, en su concepto abstracto, como ciencia de relaciones formales […] donde lo real, lo ideal, lo imaginario, lo intuitivo ó lo puramente racional existen, con igual validez, como objeto de nuestras investigaciones. ("La matemática" 1.2: 39)

Anticipating an audience of educators equipped to follow his recommendations, the author proposes a pedagogical method based on the progressive learning and understanding of the correspondences between real life and advanced representations of it. To illustrate this process, he explains how integer numbers can be assimilated as the irreducible elements of any combination in nature. Concepts of equality, inequality, or subordination, among others, can be expressed as abstractions of the logical relations established among these numbers. As the author reminds us, "[l]a matemática tiene parcialmente su realización en la Naturaleza; en ésta simultáneamente se realizan las leyes del número aplicadas á variedad de objetos; espacio, tiempo, fuerza" (40). In that way, learning basic notions of arithmetic provided the conceptual structure to understand more advanced mathematical principles, like those embedded in the physics that later could be applied in industry.

In Spain the process of industrialization strengthened the connections between scientific and technological development, and pushed, at the governmental level, a complete reformulation of ideas about the uses of science and the importance of scientific education. This was not entirely a nineteenth-century novelty. The establishment of scientific inquiries as a national priority and a matter of State, for instance, had an important antecedent in Felipe II's court during the sixteenth century. The king had identified mathematics and astronomy as sociopolitical tools and, as such, practical devices to exercise power. This emphasis on the practical aspect of science, nonetheless, produced the disassociation of spaces dedicated to the creation of knowledge and the centers to perfect its applicability at the educational level. This conceptual division complicated, and in a sense prevented, the formation of a strong Spanish scientific tradition comparable to what emerged at the time in France and England, yielding a common perception that there was a complete absence of scientific development in Spain.[9]

In spite of the supposed transition towards a progressive political system after the liberal revolution of 1868, the conservative vision established during the Restoration ended up restricting scientific development in the country even further. With strict control over higher education curricula to prevent challenges to Catholic dogma, conservative approaches to education obstructed the diffusion of modern concepts and ideas, thereby delaying technological advancement and impeding national progress. The analyses published in *El Progreso* not only responded to this political and social struggle, but also to the weaknesses of an unsophisticated scientific community. Advancing ideas on the historical development and philosophical conceptualization of mathematics, the journal introduced in Spain topics like Non-Euclidian Projective Geometry, Number Theory, and Abstract Algebra through articles, bibliographical reviews, and biographical sketches. Thus, by dealing with current problems discussed in the most important centers of knowledge around Europe, García de Galdeano made explicit his goal of incorporating mathematics in the development, modernization, and progress of the country. He assured his readers that they would find "recompensa a sus nobles esfuerzos en la satisfacción que les produzca el haber contribuido a elevar el nivel científico de su patria, obra á la cual debemos concurrir todos los que nos interesamos por su prosperidad en la medida de nuestras fuerzas y en la esfera de acción en la que cada uno se mueve" ("A nuestros lectores" 2.13: 6).

Reflections on the need to improve scientific education became even more pronounced when the journal reappeared in 1899 after a publication gap of more than four years.[10] The urgency with which the periodical was reopened not only responded to the atmosphere of national pessimism after the 1898 disaster, but also, as historian of science Mariano Hormigón explains, was a direct reaction to the government's plans to reform the university system (88). In García de Galdeano's view, the project led by the *Ministro de Instrucción Pública* (Secretary of Education), Antonio García Alix, threatened the few advances in scientific education achieved in the country during the second half of the nineteenth century. It is in this context that the marked interest of the author in the German structures of teaching, researching, and applying sciences is of the utmost relevance. Whereas in Germany there was a proportional promotion of pure and applied sciences, in Spain the lack of a strong scientific tradition complicated and unbalanced the

allocation of educational resources on both the theoretical and practical fronts, a deficiency that García Alix's reform reinforced. To counteract this structure, García de Galdeano defended the implementation of a new model of higher education that, following the German framework, would promote the emergence of a local scientific culture. However, in its conception, this plan presented many inconsistencies. Not only was the German system internationalist and interdisciplinary by definition, relying on a national science already in place, but the very idea of adopting a foreign system was incoherent with the author's goal of creating the conditions to consolidate a local scientific identity.[11] In addition, the German model entailed the progressive development of scientific skills, favoring students' experiential learning first, to later focus on theoretical instruction. As his proposal reveals, García de Galdeano agreed with this approach and encouraged its implementation in Spain. However, in multiple instances the author also emphasizes that, in the formation of scientists, pure knowledge should always come before empirical understanding. These inconsistencies responded in part to his attempt to reconcile the urgency of changing the system of education to materialize a local scientific tradition, and the long-term implications that this transformation could have. Similar contradictions, in the context of reconciling the spiritual character of national identity with the material nature of scientific inquiry, would further complicate the ways in which the journal approached the tension between science and religion.

Foreign Models and the Problem of Religion

According to Richard Olson, science became fundamental in the devising of political and social strategies during the nineteenth century (2, 21). This was particularly evident in Germany, France, and England. In these countries, the theoretical pillars of scientific development reached the political and economic elites, who turned to science seeking answers and justifications for the social transformations that industrialization spawned. Thus, science acquired a cultural status and the appropriation of scientific knowledge to understand social problems turned into a tool for the administration and advancement of society. In many different ways, the contents and methodologies of scientific inquiry transformed nineteenth-century Europe, its social organization, and its political institutions. From the beginning of the nineteenth century onward, redefinitions of psychology, political anthropology, and political economics from the perspective of the philosophical study of nature became more and more common.[12] This sort of cult of nature, and the conceptualization of science as the unveiling of its secret laws, constituted some of the main sources of opposition that this new approach encountered. In Spain, for example, as Nieto-Galán notes, scientific views of society, that in principle had been well received amid the progressive environment of the revolutionary period, were later rejected as the conservative ideology behind the Restoration called into question the compatibility between scientific thought and religious dogma ("A Republican" 161-64).

The problem was one of spiritual order; that is, it centered on answering the question of how the materialism derived from scientific inquiry could be reconciled with traditional religious beliefs. French positivism and German *naturphilosophie*, for instance, illustrate two different approaches to this problem and serve as antecedents in understanding the complexities of the Spanish case. In *naturphilosophie*, physical laws had to be derived from nature, with science being understood as a mechanism to explore the creations of God; in

positivism, physical laws prevailed upon nature, and science was seen as the set of procedures to discover and make sense of those principles, their properties, and their relations. Both approaches oscillate between subjectivity and objectivity, between metaphysics and materiality. That is why there are clear connections between the emergence of romanticism and *naturphilosophie*, and between the reconceptualization of realism and the rise of positivism. The emphasis of German science on the organic greatly differed from the stress the French system gave to the causal and mechanical character of nature. In the Spanish case, Catholicism played a central role in the debate around this tension between materialism and spirituality, which ended up having consequences in the organization of higher education. The Catholic Church had authority to decide on the content, the teaching methodologies, and the lines of study available in universities. It is not a coincidence that during the last decades of the century, educators' and scientists' inaugural talks as members of the *Real Academia de Ciencias Exactas, Físicas y Naturales* insistently focused on the state of science and the way freedom of thought was affecting education.[13]

In addition, the popularization of scientific knowledge produced a collective awareness about the negative effects that the close relationship between Church and State had on education. The adherence of Spanish society to Catholicism, considered a constitutive component of national identity, had prevented a consistent questioning of the role religion had played in the limited modernization of the country. Yet, in the context of the Regeneration, Spain needed a scientific analysis of its problems and scientists able to intervene in them. It was in this respect that the spiritual component of German philosophy of science—its understanding of scientific research as a path to explore the creations of God and not to challenge his existence—became pertinent for García de Galdeano's project in *El Progreso*. In the essay "La enseñanza de la ciencia matemática en la universidad," for example, the author highlighted the capacity of mathematics to mediate between the material world and the world of ideas—the realm of "los ideales del alma humana":

> [N]os hallamos con la matemática, ciencia que parece reunir á las dos *Facultades* en un estrecho abrazo, pues mientras por un lado aspira a medir con sus cálculos y sus fórmulas los hechos ó los fenómenos de la Naturaleza, á esquematizarlos en sus fórmulas, á idealizarlos en sus leyes, por otro lado se constituye como un organismo *á priori* que radica en el fondo de las ideas y que, conforme con *nuestra* organización espiritual se desenvuelve, con fecundidad inagotable, con fuerza deductiva incesante y siempre creciente en un mundo más rico y más variado que el Universo entero. (86; my emphasis)

For García de Galdeano, mathematics was a tool for the advancement of society, but more importantly, a constitutive part of the "organización espiritual" of the individual. In addition to the incompatibility with science, the problem with religion was also one of interference with political decisions, a connection that could affect the originality and efficiency of the educational system, and, as a consequence, national modernization.

Before analyzing García de Galdeano's proposal in the context of this tension, it is important to recognize other efforts to promote the consolidation of a national science. In the field of mathematics, it is worth noting the work of Eduardo Torroja (1847-1918) and Ventura Reyes i Prosper (1863-1922). Torroja focused his career on the implementation of a systematic plan for teaching sciences and promoting scientific knowledge on the Iberian Peninsula. Reyes i Prosper advanced mathematics inquiry through teaching, researching, and publishing at the university level. In other areas, Gumersindo Vicuña (1840-1890) and Francisco Rojas (1832-1909) are particularly important as recognized authorities of modern science and its development in Spanish universities. Vicuña was a professor of physics and mathematics at the *Universidad Central de Madrid*, where he helped define the ontological characteristics of his discipline; Rojas was a professor of physics at the *Escuela Industrial de Barcelona* and a pioneer in the study of electricity in Spain. In the field of medicine, Santiago Ramón y Cajal (1852-1934) also made important contributions to the improvement of scientific education from his position as professor of histology in the *Universidad Central of Madrid*. The researcher, as Ryan Davis highlights, was aware of Spain's many infrastructural shortcomings in terms of research and instruction at the university level (314). Some of his most compelling suggestions in this regard would appear later in his text *Los tónicos de la voluntad: reglas y consejos sobre investigación científica* (1899), whose main proposal of strengthening education and fostering interest in science amongst Spanish youth concurs in many ways with the ideas put forward in *El Progreso*.

García de Galdeano's Compelling Proposal

Studies on the history of the press have noted that nineteenth-century Spanish print media worked essentially as a political arena.[14] García de Galdeano was aware of the implications that his publication could have in debates like the one on education. A larger audience could provide resonance for his ideas, and *El Progreso* could become an effective and persuasive channel of communication between the academic realm and the political sphere. This was precisely the function of journalism in the first place, as the literary scholar and politician Mario Méndez Bejarano clearly established in his *Literatura* (1902), a stand that resonates with García de Galdeano's particular vision: "El periódico es discurso escrito y dirigido al público sobre un fondo instructivo, en que el actor se propone, como el orador, convencer y persuadir" (qtd. in Ossorio vi). By identifying the social impact of journalism, Méndez Bejarano was highlighting the role of the written press as a dedicated channel of communication, one that required particular rhetorical strategies to incorporate audiences in current debates while instructing them. In this regard, José Echegaray's definition of journalism enhances our understanding of the philosophy behind García de Galdeano's endeavor:

> [Y]o considero que el periodismo, en la trama de las sociedades, es como el sistema nervioso por donde circulan las ideas, así como las vías férreas son los canales por donde circula la sangre de la producción, como el telégrafo es otra red nerviosa del organismo, pero menos espiritual que la hoja impresa que la rotativa lanza por miles de millares en todas direcciones. (59)

Information cannot be disconnected from society; it circulates in an "organic" and "spiritual" medium, communicating, as the nervous system does, emotions and ideas, though more critically, allowing the organism to make decisions and act accordingly.

The title and content of the pieces García de Galdeano dedicated to education capitalize on this organization. Delving into the science of teaching science and the institutions that allow it, the articles underscore the connections between education and the political, economic, and cultural problems of the country. One of the main arguments put forward in these essays is that scientific instruction should insist on the progressive assimilation of concepts, and not only on their memorization for practical uses. The notion that, above all, scientific knowledge needed to be useful had precipitated a heated debate among politicians and scientists, leading to a partial paralysis at the state administrative levels regarding curricular or structural changes in the educational apparatus. This separation between theoretical and practical knowledge was already present in the reform advanced by Claudio Moyano in 1857.[15] Arguably the most important reconceptualization of public education until then, Moyano's remodeling regulated the three components of the system (elementary, secondary, and university) by differentiating two stages in each level. Thus, elementary school (*primera enseñanza*) was divided into basic and advanced; secondary (*segunda enseñanza*), into general and applied studies; and university (*nivel superior*), into departmental studies and technical or professional training. In all cases, concepts, theories, and ideas were taught mainly to support the production of practical applications. Through his journal, García de Galdeano highlighted some of the most negative consequences of this utilitarian model. In Spain, for example, scientists served basically as technicians for whom degrees and experience were mostly used to solve the shortages of infrastructure and defense systems in an otherwise backward country. Philosophical reflection and theorization of science were consequently absent from the higher-education curricula, and only the most useful tools of calculation were taught at the university level. In this context, *El Progreso*'s attempt to disseminate advanced concepts and discoveries in mathematics made in other countries was, more than anything, a way to expose the underdevelopment of a system that did not encourage the capitalization of knowledge, nor stimulate its local development.

For García de Galdeano, if Spain was to be considered a modern nation, the inclusion of mathematics in the discussion about education was imperative. Deeply influenced by the German mathematician Felix Klein, the editor of *El Progreso* considered mathematics a main actor in the social and political transformation of society, and an indispensable element in the scientific cultivation of its members. However, the idea of a country renovated and empowered by scientific knowledge demanded, as in Germany, a clear definition of the role that universities and other centers of instruction (e.g., centers of practical training, engineering schools) played in both the academic system and society. In his general considerations at the beginning of "Estudios sobre la enseñanza," García de Galdeano exhorted the reader to reflect on the possibilities these spaces of preparation could offer:

> No basta para nuestra cultura científica que nos queden como centros donde se refugie el culto de las ciencias matemáticas, físicas y químicas las varias Academias y Escuelas de ingenieros, arquitectos, etc., puesto que en

> toda nación deben existir con absoluta independencia, como respondiendo á ideales diametralmente opuestos, la enseñanza científica de las Universidades y la de los Centros técnicos […] La Universidad se eleva á la idea, á lo abstracto, á la investigación que perfecciona y acrece el caudal de verdades para organizarlas en sistema. Las Escuelas y Academias técnicas se apoderan de todo lo más importante para las aplicaciones inmediatas. Aquélla aspira á lo fundamental, éstas á lo útil, y con arreglo á estas diferencias deben elevarse armónicamente en la nación los dos focos del saber científico […] ("Estudios" 3.25: 10)

García de Galdeano recommended the separation of research and instruction as tasks that needed to be carried out by different academic entities. This suggestion, in any case, did not contradict his plea for an integrated system of education in which theoretical and applied sciences complement each other. On the contrary: if, for example, mathematics was to be considered more than an instrument to apply abstract knowledge, an expression of the fundamental principles of nature, then both universities and institutes would have different but indispensable missions. Universities would privilege the space for research and education, and institutes would promote material accomplishments and factual transformations that would be achieved through the application of science.

Why was a compartmentalization of this kind never successful in Spain? García de Galdeano would later explain in "La enseñanza de la ciencia matemática en la universidad" that the concentration of social and political efforts in defining and defending national identity had made Spain an exception in Europe:

> Basta para explicar y disculpar el hecho excepcional que ofrece España […], de su aislamiento científico, el recordar la vida toda de nuestra nación que constituye su historia, y que se resume en una guerra de raza sostenida con perseverancia incansable por espacio de ocho siglos que ha concentrado allí todo el esfuerzo patrio, y que no le han permitido distraerse hacia otros fines. (67)

While other countries focused their energy on devising the best systems to materialize their modernization through the promotion of science, both in research and its implementation, Spain persisted in generating practical applications to contribute to its military campaigns. Under these conditions, scientific education was used primarily to supply the tools for material development, and research rarely enjoyed institutional support. García de Galdeano considered Spanish backwardness to be partly the result of an ideological divergence between those educators and administrators who understood science as philosophical inquiry and those who mainly saw it as a practical tool. This tension would reach its peak when the discussion focused on mathematics, a science generally considered useless if studied in its pure form. In this respect, García de Galdeano agreed with Marcelino Menéndez Pelayo in asserting that the development of the country would not be possible until society was able to see "la sublime utilidad de la ciencia inútil" (qtd. in "Resumen" 57).

Criticism of this fixation on the practical uses of science can be traced back to the first issue of the journal. Published in 1891, the opening editorial article, "El objeto y los propósitos de la actual publicación," assesses the situation of Spain by contrasting the local developments in science with important advances in mathematics produced in other European countries. Thus, after describing the work of Cayley, Sylvester, and Hamilton, García de Galdeano points out:

> Todo este movimiento general se sigue en España, si bien reducido á aquello de más esencial que contiene cuanto ofrece inmediata aplicación, ó que es un elemento indispensable para llegar al nivel de lo que hoy constituye la cultura matemática; pero esto que se circunscribe á un reducido número de personas dedicadas por su profesión á tal género de lucubraciones, no transciende a otro público más numeroso que podría aprovechar las ventajas de estos conocimientos, y aun llegar á contribuir al adelantamiento general, si se le facilitara el acceso a ideas que parecen más difíciles de adquirir al parecer de lo que son en realidad. Estas dificultades aparentes son consecuencia de ignorarse los fundamentos de las varias teorías ó ramas que constituyen las ciencias matemáticas. (2)

Considering that pure knowledge, or theory, always precedes applicable knowledge, and that the former is one of the central elements of national development, the author provides the foundational ideology that should support the whole system of higher education: a structure that through different levels of instruction would allow the conciliation of the "estudios positivos de aplicación" and the moral strength of what was known "desde antiguo con el nombre de humanidades" ("Estudios" 3.25: 8).

García de Galdeano recognized education to be moving between opposite forces: theory and application, philosophy and science, mathematics and engineering. For him, the German system of instruction, where students' preparation for research at the university level started early in secondary school (*realschule*), was a successful example of how this pedagogical reform should be executed. The emphasis on the practical and applied matters in early stages of schooling would later change pupils' expectations and achievements, once they were preparing for college in specific professional high schools (*gymnasiums*). To support this complex system, a network of what the author denominates "medios materiales de favorecer la cultura" had to be in place. These included, among others, national legislation that promoted the

> formación ó enriquecimiento de las bibliotecas, museos de toda clase, [etc.,] verdaderos palacios que reflejan la magnificencia del objeto á que están consagrados y a la vez la grandeza del pueblo capaz de elevarlos y apto para aprovecharse de los inagotables beneficios que brotan de ellos como por irradiación cada vez más expléndida [*sic*]. ("Estudios" 3.25: 8)

A structure of this sort would be the most effective remedy for the lack of a strong scientific tradition, and its implementation would make Spanish education comparable to that of the most advanced European countries.

This reformulation also acknowledged the government's demands for stronger practical instruction, one that would fulfill the immediate needs of Spain. The author's idea was to attempt a feasible restructuration of the system already in place, creating the conditions for higher-education institutions where pure sciences could be developed in the same measure as applied knowledge. In that sense, the proposed appropriation of the German model was somewhat modest. Inspired by the Krausist notion of the search for a harmonic balance of spiritual and material forces, García de Galdeano's plan mainly required a change in pedagogical perspectives. Thus, *institutos* and *academias* were to concentrate on the instruction of technical skills, and *universidades* were to focus on research. Should the State follow these recommendations, modernization would prevail and the country would produce its own national science:

> [Es necesario] crear una escuela científica nacional con iniciativas, con impulso propio, no como reflejo ó simple imitación, como producto exótico importado de otras regiones, sino como fruto de la meditación propia, de la actividad moviéndose libremente para crear en la región de las ideas, ó para expresar con estilo propio aquello que la inteligencia elaboró y asimiló á su esencia, para presentarlo con el sello de la personalidad. ("Estudios" 3.25: 15)

Regardless of the clear influence of the German model, there had to be an element of originality reflecting the national personality. Clearly aware of the particular conditions of modernization in Spain, García de Galdeano establishes a parallel between the system of scientific scholarship and the maturity of a country as a modern nation. For him, an early introduction to the applied sciences would prepare young students for the metaphysical and philosophical questions they would need to ask later, during their doctoral studies. Likewise, the nation as a whole had to be educated so its constituencies could address more elevated matters while still generating the supplies for material and immediate needs. This yearning would be partly realized with the creation, in 1899, of the *Instituto de Vacunación, Sueroterapia y Bacteriología de Alfonso XIII*, whose two main functions, scientific instruction and pharmaceutical production, integrated the national scientific modernization that the author had envisioned for the country.

Along with the article "La enseñanza de la ciencia matemática," García de Galdeano presents some reflections by Menéndez Pelayo to support his proposal. In the context of the *Polémica de la ciencia* debate, Menéndez Pelayo contended that one of the problems with the national character was its fixation with the past. In Menéndez Pelayo's view, the country's administrators were always romanticizing old glories completely disassociated from present matters, instead of exploring the possibilities that the future could offer. The idea was not to reject the past, but instead, as the author would remark,

> conocer á punto fijo nuestros aciertos y nuestros errores antiguos; pues aunque la ciencia no tenga patria, la tienen los hombres que la cultivan, y nunca medra mucho un pueblo que tiene que vivir de ciencia importada, á cuya elaboración él no contribuye, porque la conciencia de su propio atraso se lo veda. (qtd. in "Resumen" 55)

The implications of this change of mentality, as García de Galdeano would highlight, included the understanding of higher education as an organism struggling between two forces: ideology and technology. On both fronts, the national system of education needed to comprise both university and technical centers of instruction. In that way, universities would transcend their role as spaces for professional training—a mission that would correspond now to the *institutos*—to become hubs for the formation of scientists. As a result, the national science that the author advocates in his proposal consisted of the formation of scientists whose understanding of the peculiarities of the Spanish personality would allow them to develop the conceptual solutions technicians could later apply to materialize modernization.

Since the future of the nation depended on the development of practical applications to generate a solid economic ground, García de Galdeano's plans gave special consideration to technical instruction. In his view, centers dedicated to this kind of training were fundamental to develop the human resources that not only could apply knowledge to the everyday needs of the country, but in some cases would also support the administration of universities. With this division in the approaches to doing science, the author hoped Spaniards could profit from their tendency to privilege the practical over the theoretical, a trait of the national personality that had slowed down the development of a scientific tradition. It was not the case that Spain lacked the talent, as García de Galdeano recognizes: "no han faltado los destellos del genio ni los esplendores de épocas de grandeza para las ciencias y las letras" ("La enseñanza" 95). The problem was that these sparks of national brilliance had always been extinguished by the restrictions of a misconceived educational apparatus.

The constant oscillation between the recognition of the need to promote a national educational framework through the adoption of foreign models, and the demands for immediate and practical solutions to the backwardness of the country, was the inherent challenge in García de Galdeano's proposal. By the time *El Progreso* was being published, Spain lacked a system that adequately fostered scientific skills beginning with the formative levels of education (including elementary and secondary school). The specific material needs of the country required the scientific community to devise practical solutions while ensuring the effective production of national knowledge. According to García de Galdeano, this was impossible to achieve using universities as the only space for the promotion of scientific knowledge. Assuming that the generation of original ideas required a long, but structured, process of maturation, the author proposes a logical trajectory for the development of students, who would thus be able to cultivate their scientific skills along with their individual growth. In the end, he concludes:

> Todo esto producirá la ventaja de hacer apto al alumno, desde luego, á hacer aplicaciones á la Física y á la Química y entrar en el dominio de las aplicaciones concretas, dejando para las esferas del doctorado ó los últimos cursos de la literatura la parte metafísica o histórica, el estudio crítico y sintético de la ciencia, para que lo subjetivo domine sobre lo fenomenal que debe precederle como el desarrollo sensible debe preceder al puramente racional. ("La matemática" 2.7: 27)

Given Spain's exceptional condition, "por razón de nuestras vicisitudes históricas" ("La enseñanza" 94), the author understood that the simple adoption of a foreign model would not suffice to solve all problems. In Spain, the notion of education as a balanced place for the production of practical results and the conception of theoretical ideas had to overcome more complex and unresolved ideological tensions between progressive and traditional political agendas, a realm to which García de Galdeano had no access. His approach, however, would resonate with some of the suggestions Ramón y Cajal would compile in *Los tónicos de la voluntad*. For the scientist, a successful exploration of nature required more than just technical knowledge; it also implied a moral discipline whose cultivation would separate scientists from technicians (25-32).

Conceiving institutes and universities as part of a broader framework in which scientists had the opportunity to grow as scholars and as members of society, García de Galdeano also emphasizes this moral aspect of higher education:

> Pero unos y otros [los estudios de formación científica] se mueven en una atmósfera común dentro de un solo dominio que luego recorren en distinta dirección, cuando revelándose el yo, cuando reaccionando su ser sobre las influencias exteriores, le marque su vocación en la vida social á la que [el estudiante] se ha de preparar en la sección superior de los estudios que comprenden tal ó cual Facultad de la Universidad, donde ha de poder realizar la aspiración sentida ó la vocación formada allá en los albores de su desenvolvimiento material y moral. ("La enseñanza" 85)

Ultimately, the main advantage of this structure would be to revitalize interest in science, both as tool and as cognition, allowing the rise of a national scientific culture to deal with the peculiarities of the Spanish situation. Thus, the apparent vicious circle that related the lack of scientific development to the wrongful prioritization of practical education, and the absence of practical solutions to the deficiencies in the scientific education, would be finally broken.

As I have shown, García de Galdeano's ideas aligned with the romanticism embedded in the Krausist notion of a national spirit. The conception of the nation as a product of certain geographic conditions, connections to the past, and reverence of tradition was first developed by German philosophers—in his appropriation of the doctrines of Krause, Sanz del Río had also imported the ideas of Johann Herder.[16] Under these premises, the Spanish spirit was ill, and one of the diseases afflicting it was the lack of an adequate system of education. As Alfredo Sosa-Velasco notes, thinking about the country in terms of an afflicted body functioned as an alternative space for social criticism within which it was possible to diagnose with precision and authority the impediments to the consolidation of the modern nation (3). In our case, this ailment prevented the country from developing scientific knowledge, a deficiency evident to García de Galdeano in the complete absence of local advances in mathematics. Having other nations' success as a referent, the author uncovered the awkward reality of a country where scientists were unfamiliar with the history, philosophy, and pedagogical notions of their disciplines. Without these principles, there could be no real educators and teaching would mainly consist of the exposition of other people's ideas. This may be seen as an ironic conclusion,

if we consider that a large portion of *El Progreso*'s content was dedicated to the exposition of articles written by scholars in Italy, France, or Germany; accounts that frequently appeared in the journal without translation. In this sense, with the exception of the articles submitted by Echegaray or Reyes i Prosper, the form and content of the journal were the most visible evidence of the backwardness that it intended to expose.

In any case, the circulation of *El Progreso* highlights how through reflection upon education, scientific knowledge establishes relationships with the social, political, and cultural fields. In this perspective, science influences society as much as social tensions change the possibilities of scientific development. In the journal, discussions about the teaching of science, and particularly concerning developments in mathematics during this period, operated as symbolic referents for a new kind of diagnosis of the country's affliction. Under these Regenerationist parameters, García de Galdeano's proposals enabled certain sectors of society to question the importance of universities and scientific institutions. Similar efforts would lead, for example, to the creation in 1907 of the *Junta para la Ampliación de Estudios e Investigaciones Científicas*, which, among other entities, would shape Spanish science throughout the twentieth century. Although García de Galdeano's journal circulated in a difficult environment, given that, as the author remarked, "la matemática no ha tenido tantos adeptos como en otras naciones" ("A nuestros lectores" 3.25: 3), the existence of this project shows the extent to which conceptualizations of scientific education played a central role in discussions about national modernization.

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Notes

[1] The publication of *El Progreso Matemático* comprised two separate periods or series: from 1891 to 1895, and from 1899 to 1900. As a monthly publication, each edition was indexed with a volume, corresponding to the year, and an issue number employing continuous pagination. After the publication hiatus, García de Galdeano decided to restart the volume and issue counting, and added a series number in order to distinguish 1891's Volume 1 from 1899's Volume 1.

[2] In 1898, the loss of the last colonies evidenced the political and economic decline of Spain. As Agustí Nieto-Galán comments, this loss provoked public debates in which the country's scientific capacity was called into question ("A Republican" 164). To progressive thinkers, this situation was the result of a degenerative process, a disease derived from the absence of scientific development. See also López-Ocón 305, 334ff.

[3] Mariano Hormigón, Elena Ausejo, and José Manuel Sánchez Ron (1992, 2000), among others, have approached the work of García de Galdeano from an historical and biographical perspective. For criticism on the non-specialized work of Ramón y Cajal see, among others, Ryan Davis, Alfredo Rodríguez Quiroga, José Manuel Sánchez Ron (2006), and Alfredo Sosa-Velasco.

[4] It is worth noting here the work of José Echegaray, Santiago Ramón y Cajal, and, to some extent, the ideas of García de Galdeano's disciple, Julio Rey Pastor. See, for example, Echegaray's and Ramón y Cajal's inauguration speeches at the *Real Academia de Ciencias Exactas, Físicas y Naturales* in 1866 and 1897, respectively, and Rey Pastor's inauguration speech at the *Asociación Española para el Progreso de las Ciencias* in 1915. As for the relationship between scientific development and the consolidation of the modern nation-state, see, among others, Cañizares-Esguerra 23, 41; Gellner 118ff; and Nieto-Galán, "The Images of Science" 77ff.

[5] Here I follow Bourdieu's understanding of symbolic frameworks in which particular rules determine the interaction between cultural actors and their historical milieu (140-44).

[6] In 1894, *El Progreso*'s issue 48 featured a detailed list of subscribers that included at least 80 entries, with names like José Echegaray, Eduardo Torroja, the *Ateneo de Madrid*, the *Real Academia de Ciencias de Madrid*, and the *Facultad de Ciencias de Barcelona*.

[7] José Echegaray, Rafael Altamira, Joaquín Costa, and Manuel de la Revilla are among the scientists, intellectuals, and politicians who supported this idea. See Díaz 295ff.

[8] For example, some advances in mathematics made during the first half of the nineteenth century challenged the methodological preoccupation of realism, and in particular naturalism, with the communication of truth through literature. Naturalist writers attacked problems by classifying the actions, determining their causes, and explaining the effects; they had to operate following a set of principles linking the environment and the individual. In that sense, mathematics served as model, theory, and metaphor of society. Science, especially scientific ideas and developments, can be understood here as the kind of web Katherine Hayles has in mind when she ponders the circulation of language and culture in a context clearly organized around the progresses of scientific knowledge (9-12, 21).

[9] Examinations on the origin, causes, and consequences of this perception, and the reality behind it, would provoke a heated debate later known as the *Polémica de la ciencia española*. For a detailed account of the early antecedents of the debate, see Jorge

Cañizares-Esguerra 106-10. For a discussion on the polemic during the nineteenth century, see Sánchez Ron, *Cincel* 130ff.

[10] Due to financial problems, *El Progreso* closed its doors in 1895. This unfortunate outcome evidenced once again the precarious situation of scientific education in the country. The lack of support, both from official and private sources, emphasizes the urgency of García de Galdeano's denunciation and the quixotic nature of his endeavor in this context. In spite of these limitations, the journal briefly reappeared for two more years, beginning in 1899. See Hormigón 88.

[11] See Giorgio Israel for a discussion on German and Italian national scientific structures.

[12] See Hacking 5, 39; and Olson 2, 21, 87, 250ff.

[13] In 1866, for example, Jose Echegaray read to the members of the *Real Academia de Ciencias Exactas, Físicas y Naturales* a speech entitled "Historia de las matemáticas en nuestra España." This talk also contributed to the *Polémica de la ciencia*, as it questioned the possibility of scientific progress under the strict supervision of the Catholic Church. As José Manuel Sánchez Ron indicates, Echegaray's speech sparked a long debate between intellectuals who saw religious tradition as an obstacle to scientific advancement, and those who opposed this idea (*Cincel* 130). Among the latter, Marcelino Menéndez Pelayo stands out with studies on Spanish science and scientific tradition, like the volumes *Polémicas, indicaciones y proyectos sobre la ciencia española* (1876) and *La ciencia española* (1887-1880).

[14] See, for example, Botrel and Sánchez Agusti.

[15] At the moment *El Progreso* initiated its activities in 1891, the projects of educational reform had been limited to those of the *Plan* Pidal (1845), the *Plan* Pastor Díaz (1847), and the *Plan* Seijas (1850). Some of these early attempts to reformulate higher education had ended up doing more harm than good. The *Plan* Seijas, for instance, centralized the university system authority in Madrid, making it impossible for other institutions in the system to confer the degree of doctor in sciences. In 1854 circumstances changed with the creation of the *Ministerio de Fomento* (Ministry of Development). Under its support, in 1857 the *Plan* Moyano would make one of the most important contributions to modernize education by integrating the teaching of science into the different projects of national development.

[16] Herder's notion of the existence of a national genius—collective features that define a country's psychology—was particularly embraced by Francisco Giner de los Ríos, one of Sanz del Río's followers and most prominent promoters of Krausist ideas on education, for whom literature and philosophy were the measures of the affective and intellectual breadth of national culture. See López-Morillas 87-89, 115.

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