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The Person behind the Mann Report: Charles Riborg Mann as an Influential but Elusive Figure in Engineering Education

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(A Work in Progress)

Engineering schools, like all institutions of learning, are slow to undertake educational experiments. It is sometimes easier to start a new school than to try an educational experiment in an old one.

--Henry S. Pritchett, President of the Carnegie Foundation
Preface to *A Study of Engineering Education* (1918)

I. Introduction: How a Report Written Over 100 Years Ago Can Promote Change Today

Scholars who have studied engineering education on a scale larger than individual courses and classroom practices will not be surprised by Henry Pritchett's observation that it can be easier to start a new school than to change an existing one. What is surprising, however, is *when* he made the observation: in 1918, only about 50 years after engineering was established as part of the higher education system. He made the statement in the preface to the earliest comprehensive report on engineering education in America, *A Study of Engineering Education: Prepared for the Joint Committee on Engineering Education of the National Engineering Societies* (1918) [Seely, 1999; Cheville, 2014; Akera, 2017]. It is usually referred to as the Mann Report not only because that title is much more manageable but also because it was authored by a single person, Charles Riborg Mann (1869-1942). Although the Mann Report is consistently mentioned in historical treatments of engineering education, those treatments typically focus on the report rather than its author. This paper focuses on the author, the ambitious proposals for systemic change that he advocated, and the expertise and experiences that put him in a position to analyze the system of engineering education and provide an evidence-based rationale for change. One of the most valuable lessons this exploration yields is the value of a historical perspective in defining and addressing contemporary problems in engineering education.

II. Toward an Inferential Biography of an Elusive Subject

Semantic Scholar (an AI-enabled search system) categorizes Mann as "highly influential," yet it appears that the most extensive account of his life is a brief biographical sketch in the 1922-1923 edition of *Who's Who in America* [Marquis, 1922]. That sketch forms the outline of the chronology presented here. Mann was born in Orange, New Jersey on July 12, 1869, shortly after the passage of the Morrill Act of 1862 and the creation of "the land-grant institutions that gave basic shape to the U.S. approach to engineering education" [Akera, 2017, p. 1].

His career followed a typical path for the first 25 years. He earned an A.B. from Columbia in 1890 and an A.M. in 1891. In 1896, he received a Ph.D. in physics from the University of Berlin. He married in June of that same year and took a position at the University of Chicago, where he progressed from research assistant in physics to instructor, assistant professor, and associate professor between 1896 and 1914. His interest in education at the high school and college levels is apparent in publications from this period, but it is not clear how he acquired the expertise in education that qualified him to be the principal investigator for the Joint Committee on Engineering Education, a position he held from 1914-1918.

We do know that he received an honorary Sc.D. from Lafayette College in May of 1918 and that the commencement program identified him as Professor of Education and Educational Research at the Massachusetts Institute of Technology and Chair of the Advisory Board of the Committee on Education and Special Training at the Department of War. From 1922-1934, Mann served as director (chief executive officer) of the American Council on Education (ACE). He published on various topics related to education until 1938 and died in 1942. His papers are deposited at the University of North Carolina at Chapel Hill.

The scant nature of the biographical record on Mann makes him an elusive subject, very different in domain but similar in other respects to William Shakespeare, another prolific author about whose life we have a tantalizingly scant body of evidence apart from his writing. In his *Introduction to Literary Biography* (2009), Michael J. Benton argues that treating "all but invisible" biographical subjects requires "a shift from the man to [his] ideas and thinking. . . .[his] thought as represented in his works. . . .The range, depth and variety of thinking are such that, when reading his works, we feel we are being given access to the 'biography of a mind'" [p. 67]. Benton calls this kind of biography "inferential" because it infers the author's ideas and habits of mind from his writing.

The inferential approach seems particularly suited to Mann because the volume of publications he produced is far greater than that of publications about him. I have not been able to locate an authoritative, comprehensive listing of his publications but have so far determined that they include 17 articles and reports published in *Science* between 1902 and 1914 in addition to those listed in the table below. (A more detailed list appears in the appendix.)

Publications of C.R. Mann *A Partial Bibliography*
(1894) *Hermann von Helmholtz-the Man and the Teacher* (first author W.F. Magie)
(1895 and 1896) A dissertation published in German (*Ueber Entmagnetisirungsfactoren kreiscylindrisher Stabe*) and English (*Demagnetization of Cylindrical Rods*)
(1902) *Manual of Advanced Optics*
(1905) A physics textbook (*Physics*; co-authored with George Ransom; multiple editions)

(1910) *Physics Teaching as It Is and as It Might Be in Wisconsin Schools: Papers Read Before the Wisconsin Teachers' Association*
(1910) "Physics and Education" in *The School Review*
(1916) "A Study of Engineering Education" in *Engineering Education* and *Columbia University Quarterly*
(1918) *A Study of Engineering Education: Prepared for the Joint Committee on Education of the National Engineering Societies* (Carnegie Foundation for the Advancement of Teaching)
(1919) *The American Spirit in Education* (War Department)
(1919) *The Committee on Education and Special Training: A Review of Its Work in 1918* (C.R. Mann, Chair; Civilian Advisory Board, War Department)
(1922*) Report of the Committee on Chemical Engineering Education of the American Institute of Chemical Engineers* (co-author R.T. Haslam)
(1925) *Vocational Guidance for College Students: Reports of Two Conferences of the National Research Council* (co-author L.L. Thurstone; National Research Council)
(1926) *Army Organization in Industry* (presentation to the American Management Association); also published as *Education in the Army 1919-1925* (American Council on Education)
(1928) "Finding Potential Leaders: What Does a Leader Do? (co-author Harlow Stafford Person) published in *Personnel Methods: Report of Progress of the Committee on Personnel Methods* (Eds. C.R. Mann, D.A. Robertson, M.E. Haggerty, J. B. Johnson; American Council on Education)
(1930) *Federal Relations to Education* (American Council on Education)
(1930) *Manual for Teachers of Classes of Illiterate Adults: Tentative Suggestions* (with National Advisory Committee on Illiteracy; American Council on Education)
(1938) *Living and Learning* (American Council on Education)

This list of publications and the range of subjects on which Mann published present a formidable challenge to any researcher who seeks to understand Mann's career, but they also reflect the breadth of perspective that equipped Mann to be a systems thinker who grasps the intricacies of what Alan Cheville (2014) refers to as "the emerging and emergent complex system. . . .of which engineering education is a part [the word "system" being used not] in the reductionist engineering sense, but the integrative sense of "a set of connected things or parts forming a complex whole"' [p. 15 and p. 1].

The remaining sections of this paper (1) discuss why *The Study* is worth our attention today; (2) summarize what we can infer about Mann from publications prior to the report and from Mann's association with the American Council on Education; and (3) draw some preliminary conclusions about how Mann's proposals regarding humanistic education for engineers can be a catalyst for systemic change.

II. The Mann Report: What It Does and Why It Is Worth Our Attention Today

As mentioned earlier, Mann was the chief investigator for the Joint Committee on Engineering Education of the National Engineering Societies. This committee was formed in 1907 at the initiative of the Society for the Promotion of Engineering Education (SPEE) with collaboration from the American Society of Civil Engineers (ASCE), American Society of Mechanical Engineers (ASME), Institute of Electrical Engineers (now IEEE), American Chemical Society, American Institute of Chemical Engineers (AIChE), and American Institute of Mining Engineers. A few years into the project, the Joint Committee recognized that they needed "some one trained in applied science, who should devote his entire attention to the study, working under the general direction of the Committee and in touch with it" [Mann, 1918, Introduction, p. v]. There is no indication of how Mann was chosen to be that "some one" or how he gained the expertise in educational psychology, administration, or curriculum design that the report reflects, but it seems apparent that he was more than equal to the task.

In addition to gathering large amounts of statistical information on enrollments, admissions, degrees granted, expenditures, and faculties, Mann organized a series of visits to 20 schools identified as typical. The idea was not to conduct "a complete survey of engineering schools or a grading of them into classes as good, bad, or indifferent," [p. 26] but rather to gather information from a representative group of schools that could be used to generate a reliable account of present conditions in engineering education (Part 1), the problems of engineering education (Part 2), and suggested solutions (Part 3).

The report describes pedagogical strategies and makes observations about engineering education that would be regarded as insightful and innovative today. Of those, three are particularly relevant here:

- a systems view that puts engineering curricula and institutions in the context of "relations among research, instruction, engineering practice, and industrial production" [p. 20];
- identification of the processes by which engineering education in the 50 years preceding the study had evolved from "a definite teaching plan" and "pedagogic consistency" [p. v] to a "chaotic condition" [p. 6]; and
- an integrated approach to humanistic studies that recognizes "human values and costs" as important considerations in engineering [p. 92] and has the potential to develop "a unity of purpose and outlook which will be a great asset in developing a professional consciousness among engineers" [p. 97].

Mann takes an outcomes-based approach to curriculum design that is recognizably the same as that used in Engineering Criteria 2000 (EC2000). Like the framers of EC2000, Mann recognizes that STEM competencies are necessary but not sufficient for successful engineering practice. A crucial difference is that Mann provides a solid base of empirical evidence drawn from interviews with and surveys of practicing engineers and the people who hire, supervise, and promote engineers. Where EC2000 simply lists the outcomes to be achieved in the curriculum, Mann conceptualizes the curriculum as a system consisting of three highly interrelated elements: (1) knowledge of engineering science, (2) skill in technique of application, and (3) judgment in the appraisement of values.

By extension, he conceptualizes engineering projects as system optimization problems: "In every engineering project the overlapping claims of these three essential factors [listed above] must be harmonized with respect to the two fundamental elements of production, namely, *materials and men* [emphasis added]" [p. 109]. The use of the word "men" reflects Mann's awareness that the human dimension is central to engineering practice and, by extension, that cultivating the ability to manage the human element is an essential part of engineering education. His emphasis on harmonizing elements rather than creating a hierarchy sets him apart from other authors of reports on engineering education and suggests that he provides the basis of an approach that can move engineering education beyond the persistent social-technical duality that has characterized it so far.

Mann's thinking is particularly relevant because he discerns a feature of engineering education that was not recognized by the framers of EC2000 and helps explain why the new assessment approach did not transform engineering education as had been hoped: "the reverence for departmental autonomy" in curricular design [p. 65]. As he explains,

> Since every competent specialist is always an enthusiast over his specialty, there is no limit to the number of hours he would like to fill or the amount of information he would like to impart to students. . . .Therefore *congestion of the curriculum is inevitable* so long as *each department remains sole arbiter of the content* of its courses, and there is no coordination among departments with respect to the amount and the nature of the subject-matter in courses [emphasis added] [pp. 56-57].

He refers to the administrative structure that creates congestion as the autonomous-department type and contrasts it with the cooperative type, which has a "coordinating center" [p. 30]. The autonomous-department type generates what he terms centrifugal forces. The cooperative type used in the military generates centripetal forces because it is based on cooperative effort and coordinated action. Throughout his career, Mann was both a proponent and a practitioner of cooperative effort and coordinated action.

His plan for redesigning engineering education emerges most clearly in chapter 8 ("The Curriculum") and chapter 9 ("Specialization"). Having already defined "the larger problems of engineering education" and identified potential solutions to those problems, he considers "how the various conceptions presented may be integrated in a consistent and workable curriculum" [p. 87]. Mann proposes "several radical changes from current practice" based on the organizing principle of a core curriculum that is required for all students regardless of major. The core would be defined by "the facts, principles, and processes that are essential elements in the equipment of every engineer [and consists of] of three distinct parts, namely, science (mathematics, chemistry, physics, and mechanics), mechanic arts (drawing and shop), and humanities (English and foreign languages)" [p. 89].

Additional changes he advocates include:

1. Reduce the number of required credit hours per week to no more than 18;
2. Limit the number of courses taken simultaneously to no more than 5;
3. Devote much of the first 2 years to an "orientation" that shows how the principles taught as part of academic subjects (such as trigonometry) are used in practical work (such as surveying);
4. Use experience of practical engineering work to appeal to professional ambition, arouse enthusiasm, provide training in practice, and demonstrate the connections between abstract concepts and the concrete realities of engineering work;
5. Emphasize widely applicable principles rather than highly specialized details;
6. Devote "considerable attention. . .to humanistic studies like English, economics, sociology, and history, not merely because of their practical value to the engineer, but also because of their broad human values" [p. 88];
7. Provide "some conception of business management and of the most intelligent methods of organizing and controlling men" [p. 88];
8. Place the experimental study of education "on a basis of unquestioned respectability [as] one of the surest and most expeditious ways of winning academic advancement" [p. 89];
9. Take a structured approach to providing "personal participation in industrial work" as part of the curriculum [p. 89];
10. Provide students specializing in one area of study with courses that acquaint them with the basic principles of other courses of study; and
11. Establish the relationships among all the components of the curriculum by adopting "a classification of the subject-matter that obviously expresses the intrinsic relationships of the several component parts to the needs of every engineer" [p. 90].

Astute observers of engineering education will no doubt notice that many of these changes have still not been made in engineering curricula. As Cheville remarks, "Much of the language in the Mann report is still relevant [today] and many of the issues brought up in the Mann report are still being debated" [p. 5].

III. What We Can Infer About Mann from Publications Prior to *The Study*

Two publications prior to *The Study* illuminate the intellectual foundations underlying that report: "History of Science: An Interpretation" (1908), which was published in *The Popular Science Monthly*, and "Physics and Education" (1910), published in *The School Review.* Both provide evidence of Mann's acquaintance with multiple scholarly traditions and bodies of expertise, including educational psychology and the philosophy of history. Combined with articles of the type he published in *Science,* these two publications also provide evidence of his role as a thought leader.

In "The History of Science," we see Mann in action as a systems thinker with a historical approach. He puts sociotechnical development at the center of history and advocates an approach to science education that humanizes science. He recognizes "the various ways in which science has *cooperated with the other phases of human activity* in bringing us into our present condition [emphasis added]" [p. 314], which suggests that Mann was not operating in the technologically deterministic mindset that characterizes most reports on engineering education. Although he takes scientific and technological change into account as factors that shape engineering education, he does not see keeping pace with advancements in science and technology as the primary motivation for change.

Mann draws on the concept of "universal history" to support the argument that history should be an integral part of science education. As Mann understands it, universal history treats science—like art, poetry, and philosophy—as a product of the creative imagination of a people. As a product of collective, creative imagination, science provides insight into "distinctive epochs in history and the processes by which one epoch gives way to another" [p. 314]. It focuses not on the action of sovereigns, but rather on "the higher spiritual or psychic attitude of the more gifted of the people" [p. 314]. Thus, universal history fosters "an ever keener appreciation of the majesty, the mystery and the final beauty of humanity [and] a feeling of awe at the prodigious many-sidedness and the endless significance of human activities" [p. 316]. In this framing, the teaching of science is as much a humanistic endeavor as a scientific one.

Mann also embraces a conception of progress as driven by human aspirations: "Science is not the source of the progress of civilization [but] rather the faithful handmaid who helps us truly to satisfy the practical needs of society as they become manifest. . . .scientific problems. . .originate in either the external situations of concrete experience, or in our ideals or in both" [p. 320]. Accordingly, ideals drive progress understood as "a process of self-realization of society, and science [as] a powerful tool for the successful carrying on of the process" [p. 320]. Mann does not explicitly refer to engineering or technology in this particular article, but the views he expresses resonate with the humanistic emphasis in *The Study*.

In "Physics and Education," Mann recognizes the problems created by unexamined assumptions and the larger systems in which educators operate. The article provides an account of two different approaches to the design of high school physics education debated at the 1910 meeting of the American Association for the Advancement of Science, specifically, whether school instruction in physics should be organized around the entrance requirements of universities or the needs of learners. As Mann develops the differences in the two points of view, he identifies the tendency of scientific experts to confuse their personal experiences and opinions with expertise in education. Mann points out that experts who are reluctant to make absolute pronouncements in their areas of expertise do "not hesitate to give final decisions on matters. . .of education" without ever having studied education systematically [p. 541]. Such experts "would legislate on the basis of vague impressions retained by [their] own school days and other vague impressions received from others" [p. 541]. The observations he makes about professors of physics apply to many if not most professors of engineering today.

He extends his argument in a critique of the common practice of blaming teachers and facilities for the apparent inadequacies of high school physics instruction and focuses instead on the system that allows colleges to dictate curricular design in high schools through entrance exams. The cure, he argues, is not "better prepared teachers, better laboratory facilities, better apparatus, and an attendant who is mechanically inclined" [p. 545]. A much better remedy is "knowing boys, understanding schools, and having some idea of what a problem in education looks like and of how to go about to solve it" [p. 545]. He also emphasizes the role of enthusiasm and motivation in education: "when enthusiasm and right motive precede, not only is the mind disciplined, but the will also, leading to a firm character as well as intellectual strength" [p. 543]. The problem of teaching physics as he sees it is not "reorganization of a large body of subject-matter on a new basis—instead of being a *logical* system, it must be a *teachable* system" [p. 546]. *The Study* reveals a deep understanding of what constitutes teachability, the role that individuality and individual characteristics play in workplace success, and the ways that departmental autonomy based on engineering expertise contributes to the congestion of the curriculum.

IV. What We Can Infer About Mann from *The Study*

The Study reveals Mann as a polymath and systems thinker who facilitates cooperative effort and coordinated action and demonstrates the value of a historical perspective in defining contemporary problems in engineering education.

Mann as Polymath and Systems Thinker

In *The Polymath: A Cultural History from Leonardo da Vinci to Susan Sontag* (2021), Peter Burke defines a polymath as "an individual who has mastered several disciplines" [p. 2]. Their unusually broad knowledge base helps polymaths "see connections between fields that have been separated and to notice what specialists in a given discipline, the insiders, have failed to see" [p. 5]. *The Study* is replete with such connections, the insight about departmental autonomy being one of the most notable. Burke describes polymaths as "scholars who leave their native country, whether as exiles or expatriates, for a place with a different culture of knowledge" [p. 5]. In Mann's case, the "native country" is physics and the "place with a different culture of knowledge" is engineering education.

The estrangement that comes with moving to a different culture of knowledge puts the polymath in the role of "the outsider as innovator, examining problems in one discipline with the habit of thought of an individual trained in another" [p. 159]. His publications and the few details we have about his career reveal Mann as a polymath who acquired his expertise by multiple pathways outside of formal education in settings such as the War Department and the America Association for the Advancement of Science. Perhaps most importantly, Mann was *not* formally educated as an engineer and had not embraced what Cheville (2014) calls the "orthodoxy" of focusing primarily on the scientific and technical aspects of engineering education [p. 12].

Mann's identity as a systems thinker is closely tied to his identity as a polymath. Sytse Strijbos (2017) argues in his chapter on "Systems Thinking" in the *Oxford Handbook of Interdisciplinarity* that "systems thinking represents an important form that interdisciplinarity has adopted since World War II" [p. 291]. Mann's writings make it clear that systems thinking was being used in engineering and engineering education well before that. Strijbos identifies several aspects of systems thinking that are evident in *The Study*. Perhaps most fundamentally, Mann is "attempting to overcome ever-increasing specialization, and trying to shift from reductionist to holistic thinking" [p. 291]. Mann focuses on engineering practice as "the integral [that exists prior to] disciplinary splitting" [p. 296] and embraces the complexity of that integral rather than forcing it into disciplinary categories. In the context of systems thinking, the approach Mann uses is sometimes called a "soft systems approach" and contrasted with a "hard systems approach," which assumes that all important variables are quantifiable [p. 296]. In the context of engineering education, "humanistic" better captures the systems approach Mann uses.

Mann as a Facilitator of Cooperative Effort and Coordinated Action

Mann contributed to and led many committee efforts before he began *The Study.* As an individual working at the behest and under the guidance of the Joint Committee on Engineering Education, he facilitated cooperative effort and coordinated action on a scale much larger than he had previously. The need for cooperative effort and coordinated action is a prominent theme throughout *The Study,* but Mann does not develop the rationale for cooperation and coordination in depth in that document. He does develop that rationale systematically in a later document that reports the activities of ACE to the American Association of University Professors (AAUP).

The 1925 report opens with a description of one of the most significant cases of cooperation and coordination in higher education: the development of the tenure and promotion system. The article then develops the concept of "cooperative experimentation and study [in which] the questionnaire and the survey are yielding place to cooperative experiments. As in other fields, *so in education, compiled opinion is proving a less reliable leader than organized facts* [emphasis added] [pp. 105-106]. The text reveals that survey fatigue was a reality in the early twentieth century and distinguishes between facts and opinion. The experimental approach Mann advocates works with "relatively small numbers of cases in particular institutions" [p. 106]. It compensates for the extent to which local conditions undermine the validity of experiments at a single institution. Mann argues that "The validity of the results is more readily accepted when concordant conclusions are reached independently by different observers who have tried the same thing in different places. Cooperative experimentation and study made this possible" [p. 106].

We see results of cooperative experimentation and comparative analysis in *The Study* in both the reports of practices at different institutions and the research projects whose results are included. Cooperative effort and coordinated action are particularly important in the American educational system, which is "a system without national control, comprising a large number of autonomous units working together for the establishment and improvement of educational standards, policies, and procedures" [American Council on Education, 1959, p. 2]. Reminiscent of Tocqueville's analysis of the role of civil society in American democracy, Mann recognizes the role of private organizations that cooperate to perform important public functions.

The Value of a Historical Perspective in Defining Problems in Engineering Education

Because Mann believes that "Knowledge of the past is essential to sound progress in the future" [p. 2], *The Study* opens with a history of engineering education in the United States that begins in Colonial times and extends over approximately 150 years. Although his focus is engineering education in America, he relates developments in America to those in other countries so that the distinctive character of the American system emerges more clearly. He delineates significant trends and turning points in history and analyzes their causes. In addition to providing lots of statistics about expenditures, faculty, and students, he highlights significant early experiments that suggest possibilities for strengthening engineering education. The long historical view allows him to demonstrate that engineering curricula have evolved from an organized into a congested and uncoordinated state and to discern the dynamics that govern the system.

The value of a historical perspective becomes more apparent when we consider that authors discussing the implementation of EC2000 often attribute problems of congestion in the curriculum to recent expansion in specialized knowledge and assume that resistance to change in the face of compelling reasons to change is a relatively recent phenomenon. *The Study* makes it clear that problems of curricular congestion go back over 100 years and that thoughtful observers in the early 20^{th} century were aware of the limitations of pedagogical approaches that placed theory before application and emphasized the acquisition of knowledge at the expense of experience in applying that knowledge. The report also debunks another myth often repeated in recent scholarship on engineering education: that engineering educators have only recently realized that technical skills are not enough to ensure success in engineering practice.

V. What We Can Infer About Mann from His Association with The American Council on Education

The mission and activities of the American Council on Education (ACE) provide insight into how and why Mann came to understand the complexity and diversity of the American educational system. According to a brochure published in 1959, ACE originated in "the obvious need to coordinate the services which educational institutions and organizations could contribute to the government in the national crisis brought on by World War I" [American Council on Education, 1959, p. 3]. Organized in January of 1918, ACE was originally called "The Emergency Council on Education." It had 14 national educational associations as members: (1) American Association of University Professors, (2) Association of American Agricultural Colleges and Experiment Stations, (3) Association of American Colleges, (4) Association of American Universities, (5) Association of State Universities, (6) Association of Urban Universities, (7) Catholic Educational Association, (8) National Education Association, (9) National Council of Education, (10) Department of Superintendence, (11) Society for the Promotion of Engineering Education, (12) Association of American Medical Colleges, (13) American Association for the Advancement of Science, and (14) National Council of Normal School Presidents and Principals [pp. 3-4].

This list of institutions reflects the diversity and complexity of the American educational system and the inclusive, almost encyclopedic, reach of ACE. Realizing "that there was as much need for cooperative educational endeavor in time of peace as in time of war," the organization dropped the "emergency" part of the name and substituted "American." Until the war ended in November of 1918, "the activities of the Council were centered on the war effort" [p. 4], and ACE "performed many special services at the request of the President and various government agencies, as it did again in World War II" [p. 4]. An ongoing project of the Council is the Commission on Accreditation of Service Experiences, which was established in 1945 [p. 5]. These last details reflect the extent to which ACE engaged with the armed services as a site of educational activity and innovation.

Over time, both the membership and activities of ACE expanded, though the central function of being "a center of cooperation and coordination for the improvement of education at all levels" remained [p. 2]. Some of ACE's most impactful projects were related to examinations and tests, two of which eventually merged to create the Educational Testing Service. In addition to acting "as liaison agency between the educational institutions of the country and the Federal Government," ACE conducted investigations into specific educational problems; enlisted relevant government agencies in helping to solve those problems; encouraged and supported experiments by institutions and groups of institutions; developed research methods that became accepted as national standards; and issued publications including "widely used handbooks, informational reports, and many volumes of critical analysis of social and educational problems. . . .so extensive as to rank with those of other educational presses of the United States" [pp. 2-3]. ACE's activities resemble those of the National Academy of Engineering, with the significant difference that ACE does not elect fellows and has only institutional members. In any case, Mann's longtime association with ACE reflects his interest in and knowledge of educational systems considered holistically on a very large scale.

VI. What We Learn from Man About Humanistic Education for Engineers

Although Mann uses the phrase "humanistic studies," his vision of humanistic education for engineers is not developed explicitly or systematically in *The Study*. Thus, discerning the model is somewhat akin to archeological excavation. Two of the most distinctive features that have come to the surface so far are the importance of personal traits in successful engineering practice and the belief that humanistic studies customized for engineering students are not only more effective pedagogically but serve other purposes as well.

As mentioned earlier, Mann generated an impressive body of evidence that demonstrates the importance of personality traits in engineering. Although his discussion of "The Professional Engineer" appears near the end of *The Study,* the research and analysis presented in the chapter were undertaken at the beginning of the committee's work because the members "agreed that an analysis of the requirements of the engineering profession was one of the first essential steps in this study of technological education" [p. 106]. At least two different research approaches were used to establish an empirical evidence base that supports humanistic studies customized for engineers: (1) "personal interviews [with managers working in industry] concerning the factors that are most powerful in determining success in engineering work and most effective in building up the engineering profession" and (2) "a study of the methods of rating college graduates in several large manufacturing companies" using an approach adapted from methods of assessing competency in military contexts [p. 106].

The results were both clear and quantitative: "personal qualities such as common sense, integrity, resourcefulness, initiative, tact, thoroughness, accuracy, efficiency, and understanding of men are universally recognized as being no less necessary to a professional engineer than are technical knowledge and skill" [p. 106]. When fifteen hundred engineers replied to the question "What are the most important factors in determining probable success or failure in engineering? [they] mentioned personal qualities more than seven times as frequently as they did knowledge of engineering science and the technique of practice" [p. 106].

In the next phase of the research, "thirty thousand members of the four large engineering societies [were] asked to number six groups of qualities headed respectively Character, Judgment, Efficiency, Understanding of men, Knowledge, and Technique in the order of importance [given to] them in judging the reasons for engineering success and in sizing up young men for employment or promotion" [p. 106]. Mann reports that "More than seven thousand engineers replied to this request, and their votes placed the Character group at the head of the list by a majority of 94.5 per cent, while Technique was voted to the bottom by an equally decisive majority" [p. 107].

Subsequent studies by other researchers in the last twenty years have confirmed these results, including "Hard Evidence on Soft Skills" (Heckman and Kautz, 2012), which uses rigorous economic analysis to conclusively demonstrate that "personality traits, goals, motivations, and preferences. . . .predict success in life [and] causally produce that success" (p. i). A study conducted at Harvard in 2016 yielded similar results: 85% of job success was attributed to personality traits with only 15% of success depending on technical capability [Torun, 2018, p. 6299]. Mann acknowledges that "personal traits like integrity, initiative, and common sense cannot be taught didactically like the rule of three [but argues that] it is no less obvious that the growth of these essential characteristics in students may be either fostered and encouraged or inhibited and discouraged by the manner in which the school is organized and the subject-matter presented" [p. 107]. Throughout the study Mann demonstrates that taking a pragmatic approach to humanistic education for engineers does not require abandoning humanistic values.

Mann also provides a rationale for the integration of technical and social dimensions when he argues that "technical work is more impelling, and is, therefore, more fully mastered, when it includes the consideration of values and costs; while humanistic work becomes significant, and therefore educative, when it starts from and builds upon professional interest" [p. 93]. He recommends, then, that "study of all the political, economic, and social problems which every engineer is compelled to meet" permeate the curriculum [p. 93]. Integrating the study of such problems should give "young engineers some conception of the present social situation and of the engineer's relation to it [and could provide students with] an intelligent understanding of the meaning of engineering in modern life [and] be a powerful factor in defining the status of the engineer and in liberating his creative energies for still larger service" [p. 93].

In addition to being pedagogically superior, an integrated approach that transforms all aspects of the curriculum yields benefits for the engineering profession as a whole. He makes an analogy in which "Humanistic work that builds on professional interest" goes beyond "simple rearrangement of the old bricks in a new pattern" and involves redesigning not only the humanistic studies components of the curriculum but also "the content [and] the methods of instruction of the other course" [p. 94]. A curriculum redesigned on these principles would be one in which the humanistic content could "be the same for all, because the engineering attitude which these studies foster is the same for all. By this means it is possible to develop among the engineering students a unity of purpose and outlook which will be a great asset in developing a professional consciousness among engineers, because it tends to establish engineering standards by which to interpret and attack the industrial and social problems of the day" [p. 97]. A unity of purpose and outlook could also function as a centripetal force that could be generated without threatening the territorial boundaries of existing engineering disciplines.

Conclusion: Making Meaningful Change Requires a Systems View + Cooperative Effort and Coordinated Action

This paper has used a combination of Mann's writings and an understanding of his organizational context to create an initial version of an inferential biography. Even this preliminary analysis yields insights that justify further exploration of how Mann developed the expertise and experience to see what other analysis of engineering education could not see, including the discipline-centric administrative structure that keeps the curriculum perpetually crowded and creates the impression that there is little room for humanistic studies even when such studies are recognized as valuable.

One of the most important lessons emerging from the career of Charles Riborg Mann is the value of systems thinking and polymathic expertise in the design of engineering education. Cooperation, collaboration, experimentation, and integration are pervasive themes in his work, and he makes a strong case that humanistic studies customized for engineers can not only be more effective pedagogically but also contribute to a more cohesive identity for engineering. Beyond developing these themes, however, he identifies the forces that stand in the way of integrative activities and provides an approach to engineering that makes it easier to recognize and teaching engineering as an integrative enterprise.

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Appendix: Publications by C. R. Mann

(1894) Magie, W. F., & Mann, C. R. *Hermann von helmholtz - the man and the teacher*. Johnston Company.
(1895) Ueber Entmagnetisirungsfactoren kreiscylindrisher Stabe. [About demagnetization factors of circular cylindrical rods] Berlin: Mayer & Muller.
(1896) Demagnetization factors for cylindrical rods. New York.
(1902, 26 December) Histories and bibliographies of physics. *Science 18*(417), 1016-1021.
(1902) *Manual of Advanced Optics.* Chicago: Scott, Foresman and Company.
(1903, 02 October) [Review of the book *The Theory of Optics,* by Paul Drude. Translated from the German by C.R. Mann and R.A. Millikan, New York: Longmans, Green & Co.] *Science 18*(457), 432-434
(1905) With George Ransom. Physics. Chicago: Scott, Foresman & Co.

(1907, 01 March) The American Federation of Teachers of the Mathematical and the Natural Sciences [Meeting Report] *Science 25*(635), 338-339
(1907, 13 December) The American Federation of Teachers of the Mathematical and the Natural Sciences [Meeting Report] *Science 26*(676), 843
(1908, 03 April) The American Federation of Teachers of the Mathematical and the Natural Sciences [Meeting Report] *Science 27*(692), 528-530
(1908, 03 April) Section L, education [Association Affairs] *Science 27*(692), 528-530.
(1908, 01 May) The American Federation of Teachers of the Mathematical and the Natural Sciences [Meeting Report] *Science 27*(696), 713-714
(1909, 30 April) Report of the Biltmore Meeting of the American Federation of Teachers of the Mathematical and the Natural Sciences [Meeting Report] *Science 29*(748), 707-711
(1909, 28 May) Section L, education [Association Affairs] *Science 29*(752), 872-873
(1909, 18 June) The physics teacher's problem. *Science 29*(755), 951-962
(1909, 03 December) Physics teaching in the secondary schools of America. *Science 30*(789-798
(1909, 01 April) The American Federation of Teachers of the Mathematical and the Natural Sciences [Meeting Report] *Science 31*(798), 515-516
(1910, 15 April) Section L, education [Association Affairs] *Science 31*(798), 591-597
(1910, 06 May) [Review of the book *Broad Lines in Science Teaching,* by F. Hodson. New York: McMillan & Co.] *Science 31*(801), 706-707
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(1913, 07 March) Physics and daily life. *Science 37*(949), 351-360
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(1914, 10 April) What is industrial science? *Science 39*(006)*,* 515-524
(1916) A study of engineering education. *Engineering Education, 7*(3), 125-144. Also published in *Columbia University Quarterly, 11*(19), 56-73
(1918) *A study of engineering education: Prepared for the Joint Committee on Engineering Education of the National Engineering Societies*. Carnegie Foundation for the Advancement of Teaching: *Bulletin Number 11.* Also published Boston: Merrimount Press
(1919) *The American spirit in education*. War Department Bulletin, No. 3. Washington: Government Printing Office
(1919) Civilian Advisory Board, C.R. Mann, Chair. *The Committee on Education and Special Training: A review of its work in 1918.* Washington, D.C.: War Department
(1922) With R.T. Haslam. *Report of the committee on chemical engineering education of the American Institute of Chemical Engineers.* New York: American Institute of Chemical Engineers
(1925). With L.L. Thurstone. *Vocational Guidance for College Students: Reports of Two Conferences of the National Research Council*. Washington, DC: National Research Council
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