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Mental Discipline, Curricular Reform, and the Decline of U.S. Astronomy Education, 1893-1920

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Abstract

Nineteenth-century astronomy education rested on a powerful rationale of support within American liberal arts colleges and high schools. Descriptive astronomy was widely regarded as suitable for improving a student's "mental discipline." But the collapse of mental discipline pedagogy, along with concurrent efforts to standardize and reform secondary-level curricula, were responsible for a significant post-1900 decline in astronomical teaching. As a result, astronomy education was not broadly reinstated into secondary curricula until after the launch of Sputnik in 1957. This report demonstrates that changing relationships between disciplinary specialties and pedagogical theories provide no guarantee of sustained curricular success--a conclusion equally relevant to today's science educators.

> A course in Astronomy . . . would certainly do as much for the average high school boy or girl in strengthening the intellectual faculties, in broadening the character, in elevating and stimulating thought, desire, and purpose, and in creating a strong and pure imagination, as any other subject, whether scientific or literary, embraced within any course for high schools. --E. Miller, 1895

> In this present dark age of elementary astronomical teaching, High School instructors might about as well demand to have the stars themselves brought down to the school-room as to ask for an astronomical laboratory. --Mary E. Byrd, 1903

> To a utilitarian age astronomy seems a somewhat worn-out, useless science. --Harold Jacoby, 1911

1. INTRODUCTION

During the late nineteenth century, astronomy was a flourishing research specialty as well as an academic subject widely taught in U.S. secondary schools, academies, and liberal arts colleges. Most professional astronomers were concerned with the positional and orbital characteristics of celestial bodies, while the nascent science of astrophysics held promise of revealing the compositions, temperatures, and motions of the Sun, stars, and "nebulae" by applications of the spectroscope (Lankford 1997; see Note 1). Factory-style observatories amassed and processed enormous quantities of data according to divisions of labor that were segregated by gender (Lankford & Slavings 1990). Collectively, these actions enabled the American astronomical community to attain world leadership status by the early twentieth century. But oddly enough, at the very time when U.S. astronomy was acquiring international recognition, domestic astronomy education underwent a significant decline from which it did not recover for almost sixty years. To understand and explain this unusual situation is the principal objective of this paper.

In offering an explanation for this development, a convergence of historical factors must be examined. One such factor was the rise of experimental psychology, which gained a rapid foothold within American research universities. When a leading theory in the psychology of learning was subjected to experimental testing, the disconfirming results seemingly delivered a fatal blow to the foundations on which most nineteenth-century pedagogies, including traditional astronomy education, had rested. Second, two major committee reports issued by the National Educational Association (NEA) successively downgraded and then removed from newer secondary-level curricula all science electives (encompassing astronomy, geology, meteorology, and physiology) once deemed suitable as college prerequisites. Pushing along this latter movement were concurrent reforms of American higher education--in particular, dismantling of the prescribed classical curriculum through (a) introduction of the elective system and (b) establishment of research universities and implementation of laboratory-style instruction in the sciences. These changes were symptomatic of deeper cultural influences attendant upon the emergence of modern industrial society. A multitude of overlapping factors was responsible for the ensuing decline of astronomy education, which was not effectively reversed until the dawn of the space age in 1957.

One leading historical framework concerning this issue has been presented by Jeanne E. Bishop, director of the Westlake (Ohio) Schools Planetarium (Bishop 1977, 1979; see Note 2). Bishop assigns almost complete responsibility for the early twentieth-century decline of astronomy education to the *Report* of the Committee of Ten, issued by the U.S. Bureau of Education in 1893 (described below). Bishop’s singular explanation, however, remains unconvincing on at least several grounds: (1) It fails to recognize the importance of "mental discipline" pedagogy as a primary justification for astronomy’s inclusion in pre-1900 secondary curricula; (2) Bishop’s study does not acknowledge the measure of approval afforded the Committee’s *Report* by one of America’s prominent astronomers; (3) Her argument does not examine subsequent NEA committee actions, which hastened the removal of astronomy *as an elective* from those curricula recommended for college admission; and (4) Bishop’s thesis does not address the complex factors associated with creation of Eliot’s elective system at Harvard, nor the means by which higher education’s prescribed classical curriculum was dismantled. It is therefore necessary to enlarge the present description of nineteenth-century U.S. astronomy education and those factors which proved most influential upon its subsequent decline.

2. ASTRONOMY EDUCATION AND "MENTAL DISCIPLINE" PEDAGOGY

Astronomy had formed one of the subjects of study in the medieval *quadrivium* and was usually associated with mathematics. From colonial times to the antebellum period, the trio of physics, chemistry, and astronomy comprised the discipline of "natural philosophy." By 1860, however, five well-defined sciences were taught in most liberal arts colleges: physics, astronomy, chemistry, geology, and biology (see Note 3). Astronomy instruction emphasized the practical determination of accurate positions and times, demonstrating "utilitarian needs for . . . observations to be used in navigation and surveying." Following establishment of numerous collegiate observatories housing fixed telescopes, post-bellum astronomy remained "oriented around the colleges, their professors, and their observatories." Collegiate astronomy courses usually consisted of "recitations, lectures, and instrument and observation hours. Astronomy [education] *per se* occupied at least one full term in the junior or senior year." More advanced courses in "[p]hysical astronomy or celestial mechanics" were also taught at "almost every college" (Guralnick 1975, pp. 78, 93, 90, 84). Contemporary essays reveal little consensus on the most effective strategies for teaching astronomical principles. Most authors favored either a textbook approach, which stressed theoretical concepts of the celestial sphere, or else an empirical (laboratory) emphasis that encouraged students to conduct observations and draw inferences from the phenomena witnessed. For beginners, these activities were limited to perceptions gleaned with the naked eye; more in-depth studies might include the use of low-magnification opera glasses or, if an institution were well equipped, a small astronomical telescope. Celestial globes were among the most common types of pedagogical equipment utilized. Mechanical models (orreries) of the Sun, Earth, and Moon, which displayed phenomena of the solar system, were not as readily available due to greater expense. A true luxury was possession of a "lantern" (i.e., slide) projector and set of astronomical images to accompany it (Miller 1895).

Before 1900, astronomy courses had gained widespread acceptance as prerequisites for college admission or graduation. This status reflected astronomy’s preeminent role as a "mental discipline" subject in both secondary and higher education. A fuller understanding of the term "mental discipline," and concepts relating to the "faculty" theory of psychology, have been furnished by historian Walter B. Kolesnik. The "faculty" theory held that the mind consists of various discrete mental functions (e.g., perception, memory, reason, will, and so forth), and that education consists of "strengthening or developing the powers of mind by exercising them, preferably on difficult, abstract material, such as Latin, Greek and mathematics." In drawing the analogy between mind and muscle, psychologists argued that mental faculties "may be improved individually--as muscles are improved--through exercise" (Kolesnik 1958, pp. 4, 6). Disciplining the mind was to be achieved through a "series of mental gymnastics fitted to draw forth, exercise, invigorate, and mature all the faculties" (Joseph Payne, quoted in Kolesnik 1958, p. 18). For disciplinary purposes, the actual subjects chosen for study were considered of lesser importance than the effects which mind training was believed capable of producing. Mental discipline remained the "controlling principle of American education" throughout the nineteenth century. Only during the final decades did "signs of its subsequent loss of prestige and fall from popularity" begin to appear. Much of early twentieth-century (i.e., "progressive") education constituted a deliberate "reaction against the nineteenth-century idea of mental discipline" (Kolesnik 1958, pp. 11, 10).

Clear evidence that mental discipline pedagogy had not relinquished its grip on astronomy education is gleaned from essays published in the "trade" journal *Popular Astronomy*, founded in 1893 by Carleton College astronomer William W. Payne (see Note 4). As E. Miller, a professor of mathematics and astronomy at the University of Kansas, related, "[a] course in astronomy . . . would certainly do as much for the average high school boy or girl in strengthening the intellectual faculties, in broadening the character, in elevating and stimulating thought, desire and purpose, and in creating a strong and pure imagination, as any other subject, whether scientific or literary, embraced within any course for high schools" (Miller 1895, p. 164). Four years later, an anonymous contributor (possibly Smith College astronomer Mary E. Byrd) reminded readers of a "cardinal principle," namely that "mental growth results only from mind activity rightly directed. As the highest and best of the physical being demands that every muscle have its exercise and development, so the mind in its every capacity is to be exercised" (Anonymous 1899, p. 472). Astronomy instructors, whether male or female, embraced mental discipline pedagogy and emphasized their subject's utilitarian aspects.

Eliza A. Bowen recounted what she most desired her female secondary pupils to acquire: "not merely knowledge, but all the *mental discipline* it could afford" (emphasis added). Her methods were employed in the education of fourteen-year-old girls, for whom she made it an "invariable principle" that they do "all the *observing*, all the *thinking*, possible" (Bowen 1882, p. 300; see Note 5). It should not be concluded, however, that women instructors rather than men favored observational over theoretical studies. Male colleagues remained adamant about the importance of student observations. Herbert A. Howe, director of the University of Denver's Chamberlin Observatory, offered this recommendation: "It is best to encourage each student to observe alone, having no one else present to make suggestions or bias his judgment" (Howe 1896, p. 225; see Note 6). Payne himself considered the study of astronomy to be useful in pursuing any of three possible career options: those seeking "liberal and general scholarship," others desiring "positions of instruction in the high school, academy or college," and finally, a select few wishing to follow a "professional career." For those in the first category, astronomy provided "a source of rapidly increasing *mental power*" (emphasis added). Payne, however, believed that such "foundation work" required a "well-written, modern text book" to succeed (Payne 1896, pp. 57, 58; see Note 7). Astronomer Forest R. Moulton, who acknowledged a text's value in providing "an accurate and logical presentation of what is known of a science," nonetheless feared that its "mere rehearsal," achieved through rote memorization, did not constitute true learning. What students ought to master, he argued, was "the higher labor of discovering general principles and constructing philosophies." Teaching's main purpose, as Moulton saw it, was "to develop men and women of ideas and *mental powers*" (emphasis added) (Moulton 1897, pp. 400, 401).

By furnishing numerous examples of abstract reasoning, astronomy was regarded as an ideal subject for improving a student's mental discipline. Study of the heavens fostered a "habit of accurate observation," which revealed the inadequacies of casual visual impressions; it imbued students with the "spirit of original investigation" and encouraged devotees to seek after the truth; it cultivated a "spirit of independence" and imparted responsibility to the practitioner; it developed the "geometric imagination" and required the use of "mental pictures" to explain underlying concepts (Howe 1898, p. 375). Payne classed this "exercise and culture of the imagination" as among the most "important facult[ies]" of scientific investigation. He found the resources offered by astronomy to be "evidently exhaustless" (Payne 1896, p. 59). Astronomical study enjoyed widespread acceptance throughout the nineteenth century as a mental discipline subject.

An important extension of the mental discipline concept was that termed "formal discipline." Formal discipline argued that a transfer or improvement of mental powers, from one to another closely allied function, should occur whenever individual faculties were exercised upon a given subject. According to this doctrine, mastery of one disciplinary subject left a student's mind better prepared to assimilate the knowledge of another, equally difficult subject, than if the former exercises had not been performed. For instance, mastery of the classical languages was believed to help students more readily comprehend higher mathematics and related subjects. With the rise of experimental psychology, however, that long-held belief was put to the test and found *not* to be supported.

The first experimental challenge to the doctrine of formal discipline was presented by Edward L. Thorndike, a former student of Harvard psychologist William James. In his attempt to measure the degree of transfer or improvement from one mental function to another, Thorndike and colleague R. S. Woodworth administered a battery of perceptual tests to small groups of subjects (see Note 8). These tests examined the effects of training upon a subject's visual perceptions, measured either by their estimations of the magnitudes (lengths, areas) of geometric figures, or else by their efficiencies at identifying combinations of letters or numbers on a printed page. The results were almost wholly negative. Thorndike and Woodworth (1901, p. 250) concluded that "[i]mprovement in any single mental function rarely brings about equal improvement in any other function," no matter how closely the two appeared related. From these experiments, the much-vaunted concept of formal discipline appeared to lack an empirical foundation.

Thorndike's results are often described as having given "the 'death blow' to formal discipline" and, by association, to mental discipline as well. Although mental discipline itself was never "indicted" by Thorndike's research, the apparent conflation of those two theories hastened the latter's demise. As Kolesnik argues, "the evidence in favor of transfer of training does not necessarily prove anything about mental discipline, since the former is a much broader concept than the latter." Among educators, however, "opposition to mental discipline" often rested on the premise that "transfer cannot, does not or will not take place." Regardless of the value assigned to Thorndike's research, his investigations nonetheless "fashioned to a great extent [early] twentieth century thinking with respect to mental discipline" and its rapid discrediting within the educational establishment (Kolesnik 1958, pp. 31, 53, 30; see Note 9).

What was the impact of Thorndike's research on traditional astronomy education? Publication of these results coincided with a major turnaround in the status of domestic astronomy education. University of Chicago educator George W. Myers presented reasons in 1904 for believing that "current teaching of astronomy," namely the textbook-recitation method, was "largely to blame" for the subject's declining popularity. Myers drew his conclusions from inquiries made to high school principals, who argued that astronomy possessed "little bread-and-butter value" to people, or else suffered from "archaic and unscientific methods" of instruction--seemingly a reference to Thorndike's discrediting of the principle of formal discipline (Myers 1904, pp. 33, 35). Along with curricular revisions drafted by two NEA committees (described below), astronomy's long-standing role as a mental discipline subject had become a sudden liability. As the twentieth century unfolded, mental discipline pedagogy came to be regarded as hopelessly antiquated and deserving of limited further support.

3. NATIONAL EDUCATIONAL ASSOCIATION COMMITTEES, 1893-1899

3.1. Eliot's Committee of Ten (1893)

In July 1892, Harvard University president Charles W. Eliot was appointed by the NEA to address the problem of widespread disparities existing among college entrance requirements. Eliot chaired the NEA's Committee on Secondary School Studies, popularly known as the Committee of Ten. The Committee's membership consisted of university/college presidents, professors, secondary school principals, and the U.S. Commissioner of Education, William T. Harris. In December 1892, nine additional subcommittees, appointed by subject-matter specialty, met to discuss the curricular questions posed by Eliot. Those physical sciences which once comprised "natural philosophy" (physics, chemistry, and astronomy) were united into a single subcommittee, whose conference was chaired by Johns Hopkins University chemist Ira Remsen. Carleton College astronomer William W. Payne represented his discipline in the proceedings (see Note 10). At its conclusion, the Physics, Chemistry, and Astronomy subcommittee recommended that secondary-level astronomy instruction be reduced from a college prerequisite to an elective subject, while physics and chemistry were elevated to front rank. No explicit rationale for this decision was offered. Subcommittee members prepared lists of 50 physics and 100 chemistry experiments; no guidelines for the implementation of an astronomy elective were forthcoming, however.

The Committee of Ten's *Report* contained recommendations on four comprehensive secondary curricula, which offered concentrations in either Classical, Latin-Scientific, Modern Languages, or English courses of study. A one-semester astronomy elective was integrated within the third year of all curricula except the Classical. Each course of study was designed to offer "four years of strong and effective mental training" (U.S. Bureau of Education 1893, p. 53). In a standard account of the Committee's impact, historian Edward A. Krug notes that "[p]ractically everything" about the Ten was controversial, for reasons which "[have] never been clear." Because its members supported the doctrine of mental discipline, the Ten acquired a reputation for conservatism and obsolescence. All proposed curricula embraced the elective principle introduced by Eliot at Harvard University and supported the chairman's view that "superior mental training would result from [allowing] pupils to study those subjects in which they had [the greatest] interest and ability" (Krug 1964, pp. 39, 66, 63).

Historian Herbert M. Kliebard identifies Eliot and his supporters as *"humanist"* scholars, one of "four major interest groups" that vied for control of the twentieth-century American curriculum. For Kliebard, collapse of mental discipline pedagogy was "most directly a consequence of a changing social order," which instilled "a different conception of what knowledge is of most worth." Humanists insisted on retaining a traditional, classical curriculum, although one percolated through by an enlarging system of electives. In Kliebard's opinion, Eliot championed "the systematic development of reasoning power as the central function of the schools." The Committee's *Report* enshrined Eliot's approach, whose major purpose was to develop upright "citizens of all classes" that were endowed "with the power of reason, [a] sensitivity to beauty, and high moral character" (Kliebard 1987, pp. 10, 7, 11). More recent analysis of the Ten's recommendations has been framed within the perspective of rising industrialization, urbanization, and immigration. In the judgment of historian Scott L. Montgomery, "the attitude of the Committee. . . was that the greatest good could be done for the youth of the nation by forcing a full college curriculum downward into the high schools" (Montgomery 1994, p. 146). This policy was designed to accommodate every student's life situation but in reality paid scant attention to issues of race, class, or gender. As Krug, Kliebard, and Montgomery have noted, the Committee's *Report* drew criticism from other reformers, who insisted that what schools taught must be applicable to the needs of a *heterogeneous* student population. What had seemed like an innocuous assignment, namely the effort to standardize college entrance requirements, instead produced an influential defense of an obsolete pedagogical viewpoint.

3.2. Holden’s Assessment of U.S. Astronomy Education (1899)

An important document addressing U.S. astronomy education at all levels was authored by former Lick Observatory director Edward S. Holden and published by the U.S. Commissioner of Education (Holden 1899; see Note 11). Before receiving the Lick appointment in 1888, Holden had served as director of the Washburn Observatory at the University of Wisconsin at Madison, and as president of the University of California (Osterbrock 1984; see Note 12). Holden’s account was divided into three parts: (1) "The Teaching of Astronomy in the Primary Schools," containing guidelines on that practice; (2) "Teaching of Astronomy in the Secondary Schools," detailing his review and approval of the Committee of Ten’s *Report*; and (3) "Courses of Instruction in Astronomy Offered by Some American Universities and Colleges," a candid evaluation of graduate-level education and research opportunities. Only the second of Holden’s three divisions is examined herein. In presenting his views, Holden appears to have reflected the same "humanist" approach to education as the members of Eliot’s committee.

Holden emphasized the "authoritative nature" of the Ten’s *Report* and quoted from it concerning the "extraordinary unity of opinion" reached by its authors. He treated its conclusions as soundly based and argued that expression of a "differing judgment" would "require to be fully discussed" (Holden 1899, p. 871). Holden voiced no objection toward the elective status accorded to astronomy in the Ten’s curricula, nor to the Remsen subcommittee’s failure to provide guidelines corresponding to the laboratory experiments furnished in physics and chemistry instruction. This assessment removed any doubts concerning Payne’s appointment or his services on the Remsen subcommittee. More important to Holden was the opportunity to proffer suggestions to prospective high school students contemplating professional careers in astronomy.

Holden’s most emphatic advice was for students to "lay the widest possible foundations for their scientific knowledge" and "avoid too narrow and special a view of the world." Their training should include familiarity with one or more modern languages, usually French or German, together with a reading knowledge of Latin. If a pupil intended to follow astronomy as a profession, Holden encouraged him "to study the other sciences in his high school course rather than astronomy," because "[t]here [would] be plenty of time for that" in college. Above all, Holden advised students to "comprehend the methods of all the sciences, not merely the method of his own science" (Holden 1899, p. 876).

While Holden’s statements might be construed as supporting a diminished role for astronomy in the secondary curriculum, a more viable explanation is that his outlook reflected the convention that a liberal arts education remained the best preparation for any career, including the sciences. Holden’s remarks, while sympathetic to the Ten’s objectives, did not constitute a ringing endorsement for the primacy of physics or chemistry instruction over traditional astronomy coursework. Instead, Holden’s essay affirmed the astronomical community’s acceptance of the elective system and its approval of the Ten’s recommendations for a new century ahead.

As gauged by essays which appeared in *Popular Astronomy* before 1900, no apparent discomfort or alarm was expressed over astronomy’s reduction to an elective subject, and for good reason. At this stage, the Ten’s recommendations formed strictly a curriculum on paper; there was as yet no attempt to implement these guidelines on a national level. As with many policy statements drafted by committees, their subsequent endorsement and official adoption required years to take effect, and were themselves subjected to unforeseen circumstances and restraints. That is what the historical record reveals.

3.3. Committee on College-Entrance Requirements (1895-1899)

In 1895, a second NEA committee, consisting of members appointed by the departments of Secondary and Higher Education, was appointed to streamline and implement the guidelines Eliot had recommended (Nightingale 1899). This Committee on College-Entrance Requirements (CCER) elected Augustus F. Nightingale, superintendent of high schools, Chicago, Illinois as its chairman. The CCER's avowed intention was to "study the question of college-entrance requirements, for the purpose of harmonizing the relations between the secondary schools and the colleges" (National Educational Association 1899, p. 633).

Nightingale was imbued with the classics and taught Latin and Greek for most of his professional life. By his own admission, he had once considered Greek to be a universal prescription for college admission--a position from which he retreated cautiously. In 1894, Nightingale had publicly denounced the Ten's *Report*, on account of its laxity toward Greek in the recommended courses of study. Yet in his newly appointed role, Nightingale was thrust into defending many of the same precepts espoused by the Ten, especially their elective principle (Krug 1964; see Note 13). Having softened his once-rigid approach, Nightingale gave the appearance of a newly moderated mental disciplinarian whose allegiance remained centered on the humanities--a factor that bore important consequences for the future of U.S. astronomy education and other science electives.

Nightingale's committee envisioned its responsibility as crafting "an *American* system of education," consistent "with psychic law from kindergarten to the graduate school of the university." In the CCER's judgment, the sciences should assume an integral part of this master plan. But to achieve "uniformity in extent and method" among entrance requirements, cooperation with external professional organizations was necessary (National Educational Association 1899, pp. 635, 637). Among those which displayed an interest in pedagogical matters were the American Philological Association, the American Historical Association, and the Modern Language Association. These organizations were long involved in college-preparatory studies during the reign of mental discipline pedagogy and higher education's classical curriculum. Notable by its absence, however, was the American Association for the Advancement of Science (AAAS), founded in 1848. Unlike its professional counterparts cited above, the AAAS had devoted little attention to pre-collegiate science instruction, having been more concerned with issues of patronage and disciplinary professionalization (Kohlstedt, Sokal, & Lewenstein 1999). The American Astronomical Society (AAS), founded in 1899, was too recent in origin to have advised the CCER (see Note 14). Only limited scientific advice was secured from the NEA's newly created science department via its president, Charles E. Bessey. But as Nightingale (1899, p. 627) remarked, this group "did not furnish us with as harmonious, elaborate, and satisfactory reports as those which came from other organizations."

By not obtaining advice on science curricula from beyond the NEA's confines, the CCER was forced to accept the science department's mediocre account and its uninspired core curriculum, which was adopted almost verbatim from Table III of the Ten's *Report*. Gone entirely were electives in astronomy, geology, meteorology, and physiology--subjects which had adorned the Ten's courses of study. Further, only a single year of science study was recommended for college admission, in contrast to four years of foreign languages, two of mathematics, two of English, and one of history. This selection almost certainly reflected the dominant interests of its chairman (Krug 1964). Those science courses sanctioned by the CCER for college admission were physical geography, biology, physics, and chemistry. Nightingale's committee expressed "regret" that "[u]pon several subjects of great importance this report [was] silent." In particular, it lamented that "courses of study [had] not been prepared in geology, astronomy, and physiology--subjects which play[ed] an important part in secondary courses and which [were], to some extent, recognized for entrance to college." Here, in the committee's estimation, lay the report's "most important omission." While disclaiming that their decisions had stemmed from "any feeling . . . that these subjects [were] of relatively small importance," the CCER confessed its "omissions and deficiencies" as unavoidably due to the "conditions under which the committee worked" (National Educational Association 1899, p. 675).

How did the outlook of Nightingale's Committee on College-Entrance Requirements compare with Eliot's Committee of Ten? In their approaches to pedagogy, both appear to have been fashioned from the same mold. Nightingale asserted, for example, that "the secondary schools are for the purpose of giving the best possible equipment for citizenship and for success in life, within the limits of a four-years' curriculum." This precept was fully in accord with Eliot's conviction that the nation's schools were to provide adequate life preparation for all students. It is not surprising that Nightingale's committee reiterated many of the same arguments expressed by the Ten. While recognizing that its program of studies lay "beyond what most schools, except in the large cities, [could] offer," the CCER hoped that its curricula might be adopted as "national norms" (Nightingale 1899, pp. 626, 628). In Krug's estimate, the CCER served as "moderate revisionists," who granted admission in college-preparatory courses to modern academic subjects, including the sciences (Krug 1964, p. 141). Like those drafted by the Ten, Nightingale's recommendations proved influential in defining early twentieth-century curricula among secondary schools across much of the United States.

What, then, became of the study of astronomy? Although retained as an elective in three out of four courses of study drafted by the Ten, its virtual elimination from the Nightingale report foreshadowed a "bottom line" approach common to educational restructuring activities. Given limited resources available to most school districts, including shortages of trained personnel, time, and funding, only those science courses which counted most toward college admissions would continue to be taught (see Note 15). This outcome was not anticipated by either Payne or Holden. Had these spokesmen foreseen the consequences sketched above, each might have followed a course of action significantly different from that chosen.

3.4. Elective System, Research Universities

Reforms in secondary-level curricula mirrored others being waged within American higher education. Two related struggles marked significant departures from the rigidity of the prescribed classical curriculum. These innovations were (a) the rise of the elective system and (b) the growth of research universities with their attendant laboratory investigations.

After becoming president of Harvard University in 1869, Charles W. Eliot began the process of reforming its classical curriculum (see Note 16). Eliot undertook this step in preference to the adoption of a research university. Historian Laurence R. Veysey attributes the elective principle to Eliot's vigorous faith in the abundance of free choices and exercise of free will which underlay his philosophy of rationalistic individualism. The elective system was Eliot's administrative compromise struck between retention of a rigidly defined program of classical studies and admission of newer laboratory sciences into academe. Veysey characterizes Eliot as possessing the "wrong predilections to identify himself easily with the advanced quest for new knowledge" (Veysey 1965, p. 96; see Note 17).

The second innovation which nurtured academic restructuring was the rise of the research university. The pursuit of research had been argued by some as advancing "mental endowments" to their "highest plane" (I. C. Russell, quoted in Veysey 1965, p. 124). In 1876, the Johns Hopkins University of Baltimore symbolized the transplanted German university. Liberal arts colleges, however, proved reluctant to adopt research as their primary task because (in leaders' judgment) only morality and character development embraced timeless truths. Encapsulated in their outlook was the metaphor of the well-rounded individual, or the "Whole Man." In accordance with the faculty theory of psychology, the "ideal man was he who developed all his faculties, and so fulfilled himself" (Peterson 1964, p. 34). Both the elective system and the adoption of specialized research were opposed because they threatened the "essential, underlying unity of the college." Intellectually, these reforms "would produce one-sided men, men lacking in liberal breadth," and denigrate respect for the "Whole Man." By the end of the nineteenth century, however, research was embraced as the "most essential" function of the new university (Veysey 1965, pp. 40, 135). Thereafter, the "highest achievement" of the liberal arts college would be "to prepare its students for postgraduate study in one of the research universities" (Geiger 1986, p. 19).

4. DECLINE OF U.S. ASTRONOMY EDUCATION, 1900-1920

In an address to the AAAS in 1900, University of Michigan astronomer Asaph Hall, Jr. reflected on changes introduced to collegiate- and secondary-level instruction. As a modest concession, Hall opined, "I would not say that . . . Astronomy ought to be required for entrance to college, or required in college, but it certainly ought to stand on the same plane with Botany, for instance, and Zoology." Elsewhere, Hall related that "[a] number of High School teachers of Astronomy have told me that they were not able to obtain money for apparatus because the subject could not be offered for admission to College" (Hall 1900, pp. 16, 17).

Elimination of astronomy as a college pre-requisite impacted the publication of astronomical textbooks. After conducting an informal survey, George W. Myers reported that textbook publishers declared that "the high school audience for astronomy [was] small and on the rapid wane." Restrictions of textbook sales might, in turn, have contributed further to the decline of astronomical teaching. Myers argued that appropriate linkages should be forged between the "new astronomy" (i.e., astrophysics) and its allied disciplines, physics and chemistry (Myers 1904, pp. 36, 40). Astrophysics was to remain a subject taught only in collegiate and post-graduate laboratory studies, however.

One of the most vocal proponents of revitalizing astronomy education was Smith College astronomer Mary E. Byrd. Author of *A Laboratory Manual in Astronomy* (1899), Byrd examined many aspects of this issue and wrote prolifically to bridge apparent gaps in the pedagogical literature. In the first article of a series devoted to "Astronomy in the High School," Byrd referred in 1903 to "this present dark age of elementary astronomical teaching," wherein "High School instructors might about as well demand to have the stars brought down to the school-room as to ask for an astronomical laboratory" (Byrd 1903, p. 551). Byrd's exasperation is a clear indication that traditional astronomy education had suffered a turn for the worse. In her opinion, the unwillingness or inability of many instructors to provide laboratory-style exercises comparable to physics and chemistry instruction had led to the subject's declining popularity in secondary-level curricula. Byrd, however, did not advocate the incorporation of astrophysics into its teaching, but instead encouraged student involvement and usage of simple optical equipment, coupled with reduction and analysis of observations. Despite her best efforts, the encroaching decline in astronomy education could not be reversed.

One educator familiar with the problem's history was Indiana University astronomer John A. Miller. In 1905, Miller noted that "fairly universal agreement" existed toward the Eliot committee's proposition that "the primary purpose of the high school [was] not to fit students for college, but for life." While not an "essential element" of that preparation, astronomy, in Miller's judgment, ought to be included. He viewed as unfortunate the subject's omission "from the reports of the various committees appointed by the NEA to consider the needs of secondary schools," and added that "school officials generally seem[ed] to be hostile to[ward] it." Reflecting the humanist approach to a well-rounded, liberal arts education, Miller considered that the purposes of astronomy instruction "should not be to make astronomers, but men" (Miller 1905, pp. 415, 416, 417, 418).

The elective system's detrimental impact on the teaching of astronomy was recognized in 1906 by Jonathan T. Rorer of Philadelphia's Central High School. Citing figures issued by the U.S. Commissioner of Education, Rorer first showed that, during the 1888-89 school year, forty out of forty-eight colleges and universities required either Descriptive or General Astronomy for receipt of the B.A. degree; the remaining eight institutions offered astronomy as an elective. While comparable figures were not available for his own day, Rorer suggested that the earlier ratio had since become reversed. He also compared percentages of students who had studied astronomy in secondary schools at two periods spaced nine years apart, reporting 5.27% in 1894-95 vs. 1.92% in 1903-04; a decrease of nearly 64%. Nor were NEA committee recommendations very far from Rorer's mind when he asserted that astronomy's "daughters," physics and chemistry, were themselves "year by year attracting fewer students." It was from inauguration of the elective principle or "educational declaration of independence," Rorer concluded, that "[a]stronomers more than any other class of men" had fallen victim (Rorer 1906, pp. 342, 343).

"Men" (and women, for that matter) appeared to be losing interest in the stars, as the first decade of the twentieth century drew to a close. In contrast to the high respect that astronomy was accorded by past civilizations, "[s]idereal astronomy . . . seem[ed] to find no place in this utilitarian age," complained William Tyler Olcott in 1909. Among the reasons Olcott advanced for this predicament was "the erroneous impression . . . prevalent among the masses, that even the slightest knowledge of astronomy [was] difficult to obtain." The subject's mathematical precision, he believed, intimidated those casually interested by its findings. Olcott blamed "the writers of the textbooks on astronomy, and the teachers of the subject in our schools and colleges" for failing to maintain a popular interest. Many professional astronomers, in his estimate, "[did] not seem to be able to descend to the plane of the novice" in their works (Olcott 1909, pp. 6, 8, 9). Olcott's grievance centered on the lack of attention paid within descriptive astronomy to star and constellation identification. This dissatisfaction provided the inspiration needed to undertake the task himself. Olcott's *A Field Book of the Stars* (1907) accommodated the needs of beginning skywatchers and was followed by his well-known compendium, *Star Lore of All Ages* (1911).

"To a utilitarian age astronomy seems a somewhat worn-out, useless science," wrote Columbia University astronomer Harold Jacoby, who in 1911 noted that "[e]verywhere [astronomy] is an elective subject, and it is not elected by many students." Jacoby's historical survey reiterated that astronomy's "proper place" in the general curriculum was that of a mental discipline subject because, in his opinion, "this science has so particularly high a value in training the mind." Jacoby viewed contemporary emphases upon laboratory instruction as but a passing fancy, arguing that "[o]verinsistence upon laboratory work will cease," and "astronomy will come into its own again" once the study of science is treated "as a part of modern culture" (Jacoby 1911, pp. 258, 260, 261; see Note 18). That expectation, however, was not to be fulfilled.

If there were to be a "renaissance in astronomy teaching," from whence "shall [its] leaders be found?" This was the question posed by Mary E. Byrd in 1913, who believed that the answer lay in the "normal schools." Byrd surmised that this was the optimal place from which to select astronomy-literate teachers. She recognized that an important link in the cycle of astronomy teaching and learning had been severed and must be reforged. Unless astronomy was reintroduced as part of the training of pre-service teachers, it would not be widely taught among the nation's public schools. Byrd also hoped to dispel the erroneous notion that "astronomy and a telescope [were] inseparable," namely, that lack of the second precluded teaching of the first (Byrd 1913, pp. 2, 3). Not put off by faint-hearted excuses, she composed an eight-part sequence of lessons for *Popular Astronomy* in 1920, which opened with this explicit caveat: "In this ill-favored time for education, . . . it is, I know, daring and hazardous to throw down a challenge for genuine work. These lessons are such a challenge" (Byrd 1920, p. 33).

4.1. Progressive Education, 1920-1957

Within a still-larger historical context, Eliot's elective principle and the collapse of mental discipline pedagogy were themselves reflections of broader political, social, and economic trends that attained prominence in late nineteenth-century culture. The transformation of American society from an agrarian to an urbanized, industrialized lifestyle was particularly evident among northeastern states. Recognition of these factors prompted school administrators to reassess the functions of a public education. In place of the monolithically transmitted, subject-matter-centered curricula drafted by Eliot and Nightingale came demands for reforms that stressed social efficiency and relevancy in the classroom. As Scott L. Montgomery has argued, the metaphorical image of the machine as a "perfect organizational system" came to dominate both industrial and educational discourses. The factory system of mass production created new social templates that redefined the "rules" of educational conduct. Educational theorists strove to make instruction "more immediately responsive to the needs of the work force and the national economy" (Montgomery 1994, pp. 132, 133). Aided by improved understanding of adolescent psychology and championed by advocates of child-centered instruction, those newer curricula gradually fused into so-called "progressive" education (see Note 19). By the 1920s, it had become the "dominant American pedagogy" and retained its status through the late 1950s (Ravitch 1983, p. 43).

5. CONCLUSIONS

Astronomy education held a secure presence within the curricula of U.S. liberal arts colleges, high schools, and academies through the close of the nineteenth century. By purportedly strengthening the intellectual faculties and abstract reasoning powers, astronomy was widely regarded as an ideal subject for improving a student's mental discipline. But serious challenges to this and related pedagogical theories arose from the domain of experimental psychology. Investigations by Edward L. Thorndike served to discredit the theory of formal discipline and, by association, mental discipline pedagogy as well. With the collapse of the mental discipline model, traditional astronomy education lost its once powerful rationale of support among pre-college and collegiate curricula.

The rise of American research universities and the advanced quest for new scientific knowledge brought fundamental challenges to the preeminent status of liberal arts colleges and their traditional, classical curricula. The elective principle, introduced by Charles W. Eliot at Harvard University, became the means by which newer laboratory sciences were admitted to academe and its prescribed classical curriculum was dismantled. Actions taken by successive NEA committees to standardize college entrance requirements carried these changes downward into secondary school curricula. Science electives (including descriptive astronomy) which did not lend themselves readily to laboratory-style methods of instruction were largely eliminated. Only those science courses recommended as prerequisites for college admission would receive continued support from school district administrators and textbook publishers. The cycle of astronomy teaching and learning which had remained intact throughout the nineteenth century was largely interrupted at the dawn of the new century.

Broader social/cultural reforms were likewise associated with the transformation of American society into an urbanized/industrialized economy. Recognition of these changes prompted educators to restructure public school curricula so as to prepare students for entering the factory system of mass production. Faced with the collapse of mental discipline pedagogy, "progressive" educators began their struggles to define its worthy successor(s).By retaining earlier, textbook-recitation methods of instruction, astronomical teaching was regarded as antiquated and bearing little relevance to the "modern" industrial nation. Despite the efforts of some instructors to introduce "laboratory" (i.e., observational) methods into its practices, astronomy's continued existence as a tradition-bound, mental discipline subject remained precarious. Lacking equally compelling arguments from the political, social, or economic sectors of society, astronomy education was not widely reinstated into U.S. secondary curricula until after the launch of Sputnik on 4 October 1957 (Marché 2001).

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Notes

Note 1: Lankford delineates two dominant specialties, namely astrometry (positional measurements) and celestial mechanics (studies of orbital motion), within the "old" astronomy and compares them to the emergent "new" specialty of observational astrophysics.

Note 2: Bishop's interpretation continues to influence historical discussions of U.S. astronomy education. See Fraknoi & Wentzel (1999).

Note 3: Astronomy's utilitarian focus is further described by Warner (1979) and Greene (1984).

Note 4: Payne directed Carleton's Goodsell Observatory and its time service located at Northfield, Minnesota. Like its predecessor, *The Sidereal Messenger* (founded by Payne in 1882), *Popular Astronomy* offered a forum of current events and broader professional interests including pedagogy. For a biographical sketch of Payne, see Fath (1928).

Note 5: Bowen placed little faith in "apparatus" or "contrivances," declaring that "God's own great machinery is undoubtedly the thing to study" (p. 303).

Note 6: Howe expressed displeasure over the usage of texts, adding, "It is well to begin the study without books" (p. 226).

Note 7: Payne regarded Charles A. Young's *The Elements of Astronomy* as an ideal text: "Such a book as this should be read and re-read thoroughly and exhaustively, and it should not be laid aside, more than temporarily, until the object for which it was chosen is certainly realized" (p. 58). Payne's remarks exemplified attitudes toward mental discipline which "glorified tedium as the most effective instructor . . . and made an icon out of the required textbook" (Peterson 1964, p. 42).

Note 8: Thorndike held a position at Teachers College, New York, and Woodworth at the New York University Medical School.

Note 9: Thorndike's announcement was said to have dropped a "veritable bombshell into the educational camp" (Peter Sandiford, quoted in Kolesnik 1958, p. 34). Suddenly, "[a]n age-long tradition was challenged. The educational world was immediately up in arms" (p. 34).

Note 10: Payne (1893) specified the ten members of Remsen's subcommittee and reported that "some important changes will be advised in regard to teaching these branches in Secondary and Primary schools" (p. 91). *Astronomy and Astro-Physics*, edited by Payne and George E. Hale, was the precursor to the *Astrophysical Journal* (founded by Hale and James E. Keeler in 1895).

Note 11: Holden accepted this assignment while still director of Lick Observatory but was forced to resign his position in 1897 before it was published.

Note 12: Holden, a former student of Washington University astronomer William Chauvenet and protégé of U.S. Naval Observatory director Simon Newcomb, was steeped in theoretical and positional astronomy and acquired little if any experience in astrophysics.

Note 13: The only historian to examine Nightingale's Committee on College-Entrance Requirements, Krug characterized its chairman as the "king of NEA oratory" (p. 139). The CCER "never settled at a precise size" (p. 137), although its number hovered around twelve or thirteen. Its report "arouse[d] practically no controversy at all" and was "soon forgotten." Give the CCER's relative obscurity, Krug notes, the "giant killers of the twentieth century have occupied themselves with the Committee of Ten itself" (p. 144).

Note 14: During the AAS's early years, a low level of interest was maintained in pedagogical matters, though it remained widely diffused (Fraknoi & Wentzel 1999, pp. 196-197). After the demise in 1921 of its Committee on Teaching of Astronomy, however, "astronomy education was absent from the published record of the AAS for almost two decades" (p. 197).

Note 15: An anonymous contributor to Payne's journal asked, "Does this mean that the study of astronomy is to be abandoned in the high schools of this country? . . . An expression of opinion regarding the proposed change is desired" (Inquirer 1901, p. 279).

Note 16: Eliot's reforms took "over 25 years to complete," and were only accomplished "one by one, year by year, battle by battle," until "all the old sacred subjects" had been reduced to electives (Montgomery 1994, p. 120).

Note 17: Veysey's comparative study of Eliot and Cornell University president Andrew Dickson White reveals each to have been a utility-minded reformer. Although both men had traveled extensively in Europe, "neither wished to convert American higher education to the German [research] model" (p. 95). Eliot's stature as the "most commanding figure among all the late nineteenth-century university presidents" influenced undergraduate institutions elsewhere to adopt similar measures (p. 87).

Note 18: Jacoby supported astronomy's role as a mental discipline subject with arguments identical to those in vogue during the 1890s. He wrote, "There is no other branch of human knowledge possessing a subject matter so well adapted to produce the habit of accurate thinking. Astronomy owes its real preeminence in this respect to the intricacy of the problems it presents, to the extraordinary precision of which their solutions admit, and to the appeal it makes to the imagination by reason of the vast volumes and areas included within the scope of its problems" (p. 260).

Note 19: Philadelphia entrepreneur Armand N. Spitz, inventor of the pinhole-style planetarium projector, was a 1922 alumnus of West Philadelphia High School. Spitz once remarked that he had been allowed to graduate from "one of the newest and most progressive high schools" in that city, "without having been introduced to the stars." Spitz's statement offers further evidence of the low status accorded to astronomy education within so-called "progressive" curricula. "Spitz and the Planetarium," manuscript transcribed and annotated by Spitz's second wife, Grace (Scholz) Spitz, from Armand's recollections dictated on tape and delivered before the Great Lakes Planetarium Association (GLPA) conference in 1967.

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