DEPARTMENT OF THE INTERIOR

BUREAU OF EDUCATION

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THE COOPERATIVE SYSTEM OF EDUCATION

AN ACCOUNT OF COOPERATIVE EDUCATION AS DEVELOPED IN THE COLLEGE OF ENGINEERING UNIVERSITY OF CINCINNATI

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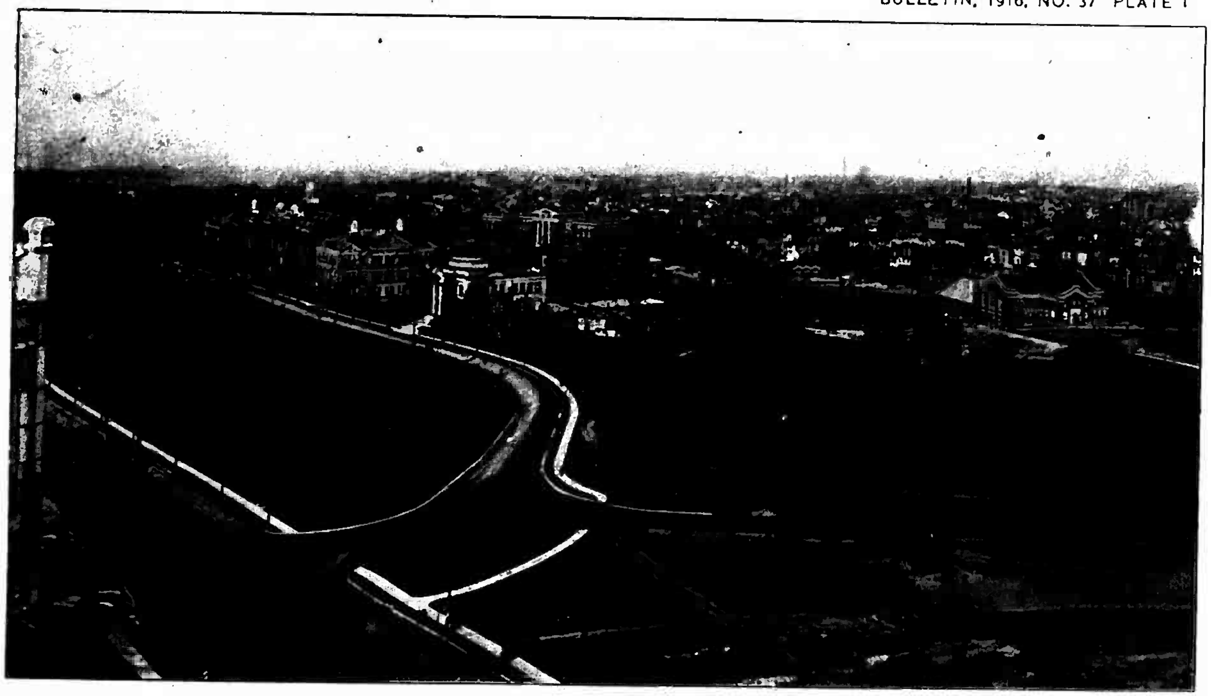

THE UNIVERSITY OF CINCINNATI.

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DEPARTMENT OF THE INTERIOR,
BUREAU OF EDUCATION,
Washington, June 21, 1916.

SIR: The cooperative system of education in the Department of Engineering of the University of Cincinnati, begun 10 years ago, is, I believe, one of the most interesting and instructive experiments in education within recent years. The importance of the experiment is due to the fact that it is not only practical, but is also based on fundamentally correct principles of education, too often forgotten in school and college work. This experiment has been the subject of many newspaper and magazine articles and public addresses, but I believe no account of it has appeared so comprehensive as that given in the manuscript prepared by Clyde William Park, of the University of Cincinnati. I recommend, therefore, that this manuscript be published as a bulletin of the Bureau of Education.

Respectfully submitted.

P. P. CLAXTON,
Commissioner.

The SECRETARY OF THE INTERIOR.

THE COOPERATIVE SYSTEM OF EDUCATION.

I. THE COOPERATIVE IDEA.

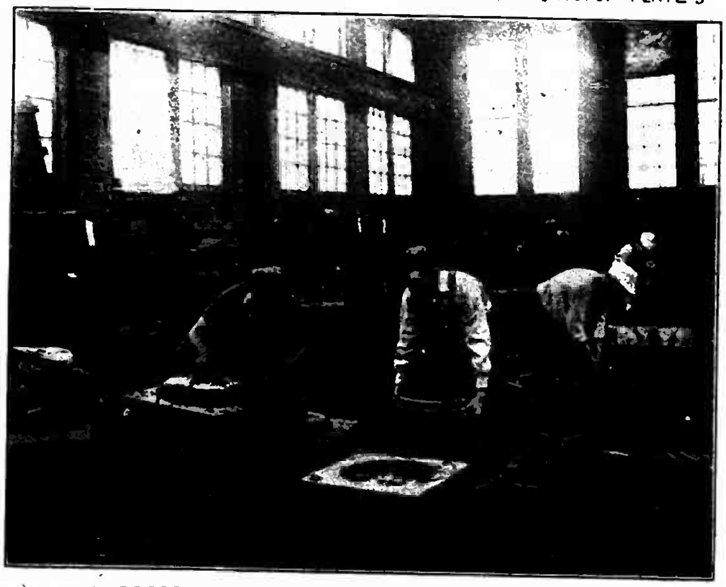
The cooperative course of the University of Cincinnati was not the product of an academic laboratory of pedagogical research; its origin was rather in an investigation of the actual working conditions of commercial engineering practice. At the time when the course was conceived, practical men were especially severe in their criticism of the graduates of engineering colleges. The old apprentice system had broken down under the strain of a complex industrial organization, and it seemed that the engineering colleges were making but little effective effort to supply the link between theory and practice. Many teachers of engineering felt that they had done their whole duty when they had taught a traditional body of theory and had seen to it that the student retained at least 70 per cent of his book knowledge until after the final examinations. A few instructors conceded the desirability of hitching theory and practice side by side, but did not believe that such an arrangement was feasible.

The plan usually considered, and frequently followed, for uniting practice with theoretical instruction was the installation of school shops. The objections to this plan, however, were so numerous as to discourage its general adoption. In the first place, if school shops were to be fully illustrative of actual practice, they would have to include miniature reproductions of electrical plants, foundries, structural iron works, machine shops, railroads, construction companies, chemical industries, and all the other vast and complicated machinery of the industrial world. To duplicate all these plants would, of course, be out of the question; and merely to represent a few typical processes would involve such tremendous expense that only a few institutions could afford the luxury. Moreover, even in the most heavily endowed colleges there was danger that the pay—and hence the quality—of the teaching force would suffer, because of the increased outlay needed for equipment. A further objection to school shops lay in the fact that they must inevitably fall behind the times in a few years. To remodel the shops and revise the shop courses frequently enough to keep pace with the swift progress of engineering development would be clearly impracticable. Neither did it appear feasible to put the school shops on a commercial basis and have the professors and students compete with business men engaged in actual production. From every angle the school shop appeared impracticable. Yet it was clear that a well-planned course in the practice of engineering would not only prepare the student better for his future work, but would also enable him to retain and understand a much larger proportion of his theory.

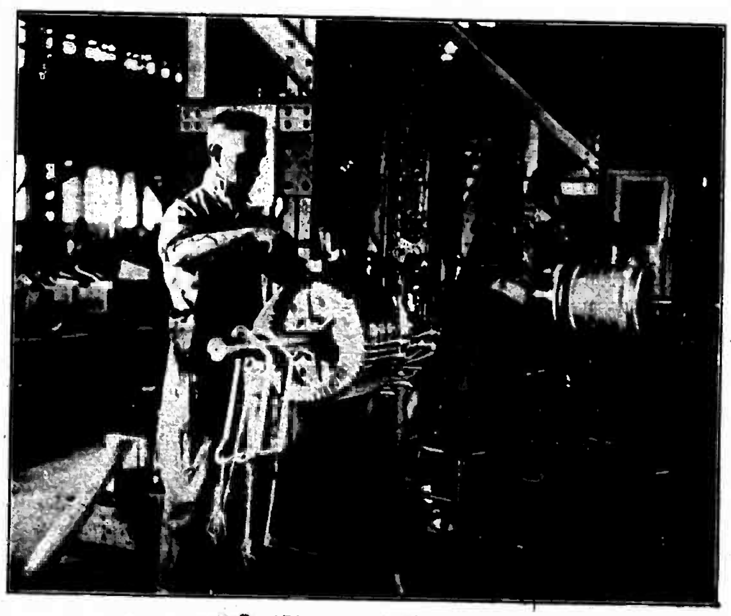
A solution of this vexing problem came to Prof. Herman Schneider in a curious way. One evening, as he was walking across the campus of an eastern university where he was teaching, he heard the answer in the blast of a Bessemer furnace at a neighboring steel plant. Instantly the idea appealed to him as perfectly simple and obvious. Here was something better than any conceivable school shop—a million-dollar laboratory, with unlimited possibilities for illustrating the applications of technical theory. In this plant many graduates of this same college would find employment, as others had done before them. Why should they not learn as students to translate their book knowledge into terms of industrial processes?

The idea was not enthusiastically received by members of the college faculty, to whom the plan was suggested. In so far as they considered the proposition, they were disposed to look upon cooperation between college and industry as impracticable, if not undesirable. Despite their skepticism, however, Prof. Schneider found his faith growing stronger as he considered more fully the possibilities of the plan. All about the college were industrial plants, to which graduates went for a two-year apprentice course upon the completion of their four years of school work. Why not combine the apprentice course and the school work into a six-year course? Then, instead of paying the school for shopwork, the students would be earning money at the same time that they were getting experience. This would enable many worthy young men to attend school who otherwise would be excluded. There would be a selection of men by tests in both theory and practice. Misfits would thus be avoided, and the best men could be developed for the work to which they were naturally adapted. The school would become a pure teaching college, since all practical experience would be obtained on commercial engineering work. A plan could be devised to coordinate theory and practice. The school could have one group of men while the shop had the other, and thus many more students could be accommodated with the same amount of equipment. The descriptive courses heretofore given by the school could be eliminated and the school time devoted entirely to theory. Young men could start at the bottom of practical work and by a selective process arrive upon graduation at positions of responsibility in the field of engineering. The school would perform with increased efficiency the functions for which it was intended, and the shop would

ENGINEERING BUILDING, UNIVERSITY OF CINCINNATI.



A. COOPERATIVE STUDENT IN A COMMERCIAL FOUNDRY.



B. ARMATURE ASSEMBLY.

return to its proper but neglected function—the training of men by means of a thorough apprentice system. Even a stronger reason was found in the influence which the system would undoubtedly have upon the student's character. For developing industry, loyalty, and self-reliance, surely no plan could be devised that would be more effective. The arguments for cooperation seemed unanswerable, but the university men were unwilling to give the plan a trial.

In striking contrast to the skepticism and indifference of the college teachers was the attitude of a number of practicing engineers, who were next consulted. Almost without exception they received the idea hospitably and expressed their belief in its feasibility. They were also virtually unanimous in saying that their own theoretical training had meant little to them upon graduation, and that to review their theory when they needed it in practice had been a painful and discouraging process. Several engineers, including the chief engineer and the other officials of a large bridge corporation, volunteered their hearty indorsement of the cooperative plan, both as an educational and as a commercial proposition.

One or two things stood out prominently in these conferences with college teachers and with practical men. It was evident that the men who trained engineers and the men who used engineers were quite as far apart as they could get, and that it would not be easy to bring about an understanding between them. It was also clear that the most difficult task would be to induce the college men to undertake the educational experiment of cooperation.

II. THE EXPERIMENTAL PERIOD.

FIRST CLASS OF COOPERATIVE STUDENTS.

It was several years before Prof. Schneider found an opportunity to test the cooperative plan in actual practice. In the meantime, he had been called (in 1903) to the chair of civil engineering at the University of Cincinnati. During the first school year (1903–4), the retirement of the president precluded the submission of plans for the new course. The plan was presented to President Dabney soon after his appointment (in 1904), but because of the pressure of regular business he was unable for some time to consider any changes. In the fall of 1905, President Dabney approved the plan and presented it to the board of directors. After considerable discussion, the board authorized the introduction of the cooperative course on a small scale, to begin with the school year 1906–7.

While the educational aspect of the cooperative plan was under consideration by the university authorities, its practical application to local industries was taken up with numerous manufacturers, superintendents, foremen, and engineers in Cincinnati. Most of these men showed interest and faith in the scheme as a general proposition; but when it came to adopting it as an actual business policy, some were chary of so radical an innovation. Typical of their objections to accepting cooperative apprentices were the statements that two men could not work alternate weeks at one machine, and that a crowd of "rah-rah" boys would disturb the shop organization. The latter objection coincided remarkably with the fear which had been expressed by some of the university instructors, that a group of "boiler makers" would destroy the scholastic atmosphere of an educational institution. By the end of a year of persistent interviewing, 12 concerns had agreed to try the cooperative system for 9 months—the college year. These firms offered employment to students in electrical and mechanical engineering courses.

The next problem was to find students who were willing to take the course. The matriculates who came to enter the regular four-year course could not be induced to try the new plan. One of the requirements adopted at the beginning was that a student who wished to enter the cooperative course in September must either spend the summer working in the shops or bring a recommendation from a firm with which he had had an equivalent amount of practical work. This requirement discouraged many prospective members of the first group of cooperative students, as it has in the case of all subsequent classes. In fact, the 28 young men who were finally enrolled chose the cooperative course solely for financial reasons. These students, however, did not last long under the strain of the preliminary shopwork. Ten hours of manual labor in hot weather and on equal terms with ordinary apprentices is a pretty severe test of a young man's stamina. On the first of September, when Dean Schneider returned from a month's vacation, he found that of the 28 men whom he had put to work in July all but 6 or 8 had quit. He then hurriedly recruited a class of young men who could not present the full 14 academic units required for admission, but who had had some practical experience and who gave evidence of fitness for engineering work. One of these students, now efficiency engineer for the Bell Telephone Co., in a Middle-West State, was admitted against the advice of his father and over the protests of three high-school principals, who had dismissed him as incorrigible. Notwithstanding their rather poor scholastic records, the members of this first class were on the whole a fairly promising group. At least, they knew what their work was to be and they seemed to catch the spirit of the new course.

The peculiar requirements of the cooperative course developed a new type of student. The "co-op.," as he was called, was alert, rugged, and independent. He was generally more serious than the "regular" student, but on occasion he displayed a sense of humor and a buoyancy which showed that, though he might be sobered by his practical work, he was not at all depressed by it. The difference lay rather in the fact that he had known the steadying influence of responsibility. Not only his personal advancement, but also the outcome of an important educational experiment, depended upon his success, and the realization of this fact seemed to give him a new sense of loyalty to his college and a determination not to disappoint those who had trusted him. It was inevitable, of course, that the "co-op." of the early days should be self-conscious. He was the center of interest in a great educational clinic, and the knowledge that he was constantly being analyzed, photographed, and written up gave him a feeling of aloofness from the rest of the student body. This feeling, doubtless, was largely responsible for his "class consciousness," for there never was a more clannish group than the members of the first cooperative class.

For a time the attitude of the other students was such as to enforce this exclusiveness. It is a pleasure, however, to record that the old animosity between the two groups of students has disappeared. The cooperative students and the others have found that they have a great many things in common and no essential differences. The very fact that their interests and experiences are in some respects unlike has made their association mutually beneficial. Community of interest, especially in athletic and social activities, has developed a wholesome university spirit. Evidence of the present solidarity is found in the prominent part taken by cooperative students in every kind of student activity. A "co-op." was president of the senior class in 1915, the captains of both football and basketball teams are "co-ops," and in all the musical, social, and other organizations there is a large proportion of cooperative students. In view of recent developments, it would be hard for either group to understand that the "ostracism of the boiler makers" was once seriously considered.

DETAILS OF THE COURSE.

At the beginning the cooperative course extended over a period of six years, including alternate weeks at the university and in the shop for each school year, and a three-months period of full-time shopwork (excepting two weeks' vacation) during the summer. Each man had an alternate; so that the shopwork was continued by students of one section while those of the other section were in school. Under this arrangement, the theoretical instruction given in the regular four-year course was combined with the practical experience of a newly devised shop-apprentice course. Theory and practice were carefully graded and coordinated and the student's work was so planned as to familiarize him, first with the simpler, and later with the more complex problems of the plant in which he was employed.

For example, in the course in electrical engineering, the first year's work was in the foundry; the next year and a half in the machine shop; the next two years in the commutator, controller, winding, erecting, and testing departments; and the remaining time in the drafting rooms. On the contract, which was signed in triplicate by the student, the firm, and the university, was a blank space to be filled in with the amount and character of the apprentice work. The details of shop and business experience were left to the dean and the head of a given department on the one hand and the superintendent of the factory on the other.

ATTITUDE OF THE COOPERATING MANUFACTURERS.

The attitude of the cooperating manufacturers, and their ideas of what was to be gained from the cooperative system, may best be stated by quoting from a paper presented by Mr. Charles Gingrich, M. E., of the Cincinnati Milling Machine Co., at the fifteenth annual meeting of the Society for the Promotion of Engineering Education, July 3, 1907. Mr. Gingrich said in part:

> The manufacturers of my city have for some time past been face to face with the very serious problem of getting the right kind of men. Our industries are diversified, including machine tool, steam pump, steam engine, and electrical shops. The machine-tool industry predominates. We are rapidly becoming known as the chief machine-tool manufacturing center of the country, but we need more technically trained men in the further development of this industry. It is our good fortune to have the University of Cincinnati centrally located among us. When it proposed to us Prof. Schneider's plan of a cooperative engineering course, the idea appealed at once to the business sense of each individual manufacturer. It promised us an immediate supply of boys of a much higher grade than those who take up the regular apprenticeship. It held out the prospect of our getting within a few years engineering graduates with practical shop experience.
>
> We have all tried to give a shop training to young men from the colleges, but it is never entirely successful. A man who has put in four years of his young manhood getting a university education can not get into the shop atmosphere, even if he does don overalls and work as a regular hand. Such men have passed beyond the age at which boys freely ask questions and learn quickly all those little details which are such an important part of the training and experience of shopmen. They feel that they can not afford to be laughed at. They do not want to expose their ignorance. Therefore they get at best only a superficial knowledge of what is going on inside the shop. I do not mean to imply that our shops are full of secrets, but I do want to emphasize the fact that they contain a vast number of things to be learned; that the only place to learn them is in the shops; and that the best way to do it is to start young and take plenty of time. The chief criticisms of modern technical education result from the fact that we try to take the shop into the school, whereas we should bring the school into the shop. The cooperative plan does bring the school into the shop.

GROWTH OF THE COOPERATIVE PLAN.

After the entire feasibility of the cooperative course had been proved by a year's trial, there remained the question of how rapidly the university could adjust itself to an increased enrollment and to a greater number and variety of industries. Plenty of students were now willing to enter the course. Over 400 inquiries from prospective students were received during the first year and a large proportion of those who inquired made formal application for admission. The scholarship records of the new applicants admitted were well above the usual requirements for college entrance, and some of the men who enrolled as first-year cooperative students had spent one year or more in academic work at other colleges. Many employers who had thought favorably of the plan, but had hitherto been reluctant to introduce it, no longer hesitated to ask for cooperative apprentices. The number of students who could be admitted, however, was limited by the crowded condition of classrooms and laboratories at the university and also by the policy of the engineering faculty. The acceptance of fewer students was favored, because it would permit a more careful selection of men and would afford a better opportunity to study the pedagogical and administrative details of the course.

By the end of the first four years of operation, which may be called the experimental period, the cooperative plan had been fully vindicated. It had shown itself to be adapted to a variety of courses, including civil, chemical, and metallurgical engineering, and to a range of industries from railroad construction to ink manufacturing. It had survived a panic and the ensuing industrial depression. The old theoretical objections, that two men could not alternate successfully at the same work, and that the "lag" on Monday mornings would be equally prohibitive at school and in the shop were disposed of once and for all by the answer that these difficulties were found not to exist in practice. If anything, "blue Monday" lost some of its proverbial languor, since the students came refreshed to each new task, with their wits sharpened by a change of surroundings and of occupation.

LESSONS OF THE EXPERIMENTAL PERIOD.

The experimental period served to teach a number of lessons, which suggested changes in the plan and operation of the cooperative course. First, the old apprentice course was too rigid to adapt itself readily to the varied and changing conditions of commercial production. It seemed advisable to abandon the ironclad contract, and modify the terms of a student's employment, so as to facilitate his being transferred from one kind of work to another when a change seemed desirable.

Then, in order to keep the proper emphasis on the instructional phase of a student's work, it seemed advisable to handle business questions through a special agency, and thus leave the members of the faculty free to consider primarily the educational value of the various kinds of shop experience.

In the further development of coordination between theory and practice, there was need for careful selection and systematic analysis of the various types of work, in order to obtain for the student the greatest possible amount of educational content from his practical experience.

The six-year course seemed to be longer than necessary. By extending the alternate weeks of school and shop work through the summer terms, the same amount of theory could be given in five years of 11 months as in six 9-month periods. From the standpoint of the shops this would be more convenient, since it would do away with the necessity of providing summer shopwork for twice the usual number of men.

Although the general scheme of weekly alternation had proved successful, it appeared that two weeks would be a more satisfactory unit than one. This was particularly true in the case of railroad work and other work outside the city. It was found that the periodical readjustments were as easy for students who worked on a two-weeks basis as for the others. A comparison of the two units showed that, on the whole, fortnightly alternation was more desirable for both school and shop work.

A revision of the curriculum also seemed advisable, and several changes were considered, including the following: Purely descriptive material, it was decided, should be eliminated, in order to secure time for a deeper study of the fundamentals. Overlapping and closely related courses should be compared in detail to avoid duplications and omissions. The relation between prerequisite and advanced courses should be emphasized, and deficiencies in a student's preparation should be reported to his instructor in the prerequisite course. Provision should be made for the recall of grades in case the student failed to retain a working knowledge of a preparatory subject. The theoretical work of the first three years in all departments should agree as nearly as possible, and specialization should be left to the latter part of the course.

Since the combination of school and shop work tends toward the rapid elimination of the physically, mentally, and temperamentally unfit, the cooperative system is in itself selective. In view of the increasing number of applications, however, it seemed worth while to investigate the practicability of a preliminary test that would eliminate in advance as many as possible of the misfits. Accordingly, a study was begun to determine a basis of selection that would discover a man's fitness to enter the course and, also, if possible, his adaptability for a particular class of work.

III. THE REORGANIZED SYSTEM.

Notwithstanding that the changes in the cooperative course were gradual and evolutionary, it is possible to cite a fairly definite date at which the experimental stage ends and the new period begins. Before the end of the school year 1910–11 the principal changes had been inaugurated.

ADAPTABILITY TO VARIOUS KINDS OF BUSINESS.

The keynote of the reorganized system was adaptability. In the industries represented by the various cooperating firms there was variety, change, life. It would not have been possible for these firms to adjust their operations in accordance with a rigid educational system imposed upon them from without; nor would it have been desirable, even supposing that the employers had philanthropically offered to surround the cooperative students with exceptionally favorable conditions. To have done this would have been to carry over into the industries the unrealities of the school shops; whereas, under the cooperative system, it was a fundamental requirement that the student's practical work should be done amid conditions of actual production. The school planned the courses, shifted the men, and otherwise continued to be the directing head, and in administrative details it adjusted itself to engineering practice. The reorganization of the course was simply a recognition of the need for a system that should be flexible without being desultory, and definite without being rigid.

BUSINESS ORGANIZATION.

In the administrative department the old form of contract was abolished and the only definite agreement made was upon a minimum rate of 15 cents an hour for all entering students. The way was opened for the immediate transfer of a student who, though unsuccessful in one branch of engineering practice, seemed worthy of a trial in some other department. Despite the fact that the proportion of misfits had been greatly reduced each year, this increase in the freedom with which changes could be made proved to be an important advantage. In order that the progress of a student might be more closely followed by those directly concerned with his school training, the business of making the transfers and planning a student's practical work was turned over to the heads of the civil, mechanical, electrical, and other engineering departments. To facilitate this work and to insure for the students the greatest degree of personal attention, each of the professors and instructors was assigned a special list of shops and a regular schedule for visiting them.

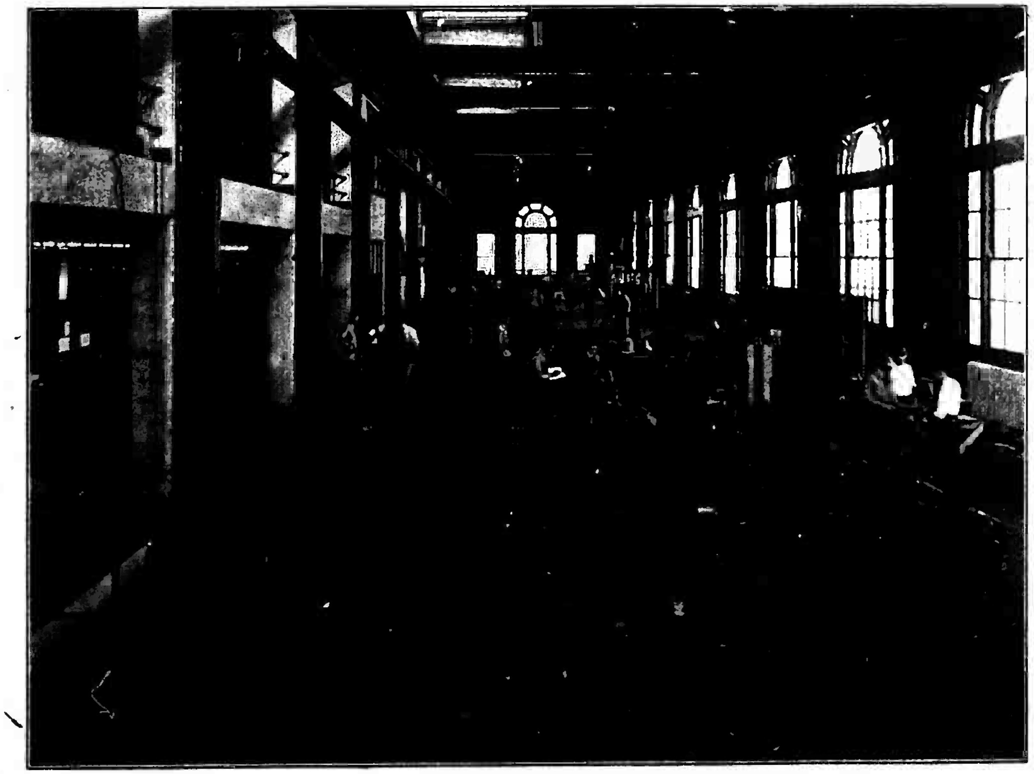
At the same time that the engineering professors were given full responsibility for the adjustment of shop and school work, they were relieved of the business details in the relations between students and employers. The commercial part of the work was placed entirely in the hands of a special field secretary in the dean's office. His duties included opening negotiations with new firms, investigating complaints from students or employers, and adjusting wages and working conditions. It was also provided that through the field secretary should be made all promotions, transfers, substitutions of alternates, and other changes affecting the employment of cooperative students.

The university cooperates with almost 100 firms, representing the principal phases of construction, manufacture, and transportation.

SHOP SCHEDULE

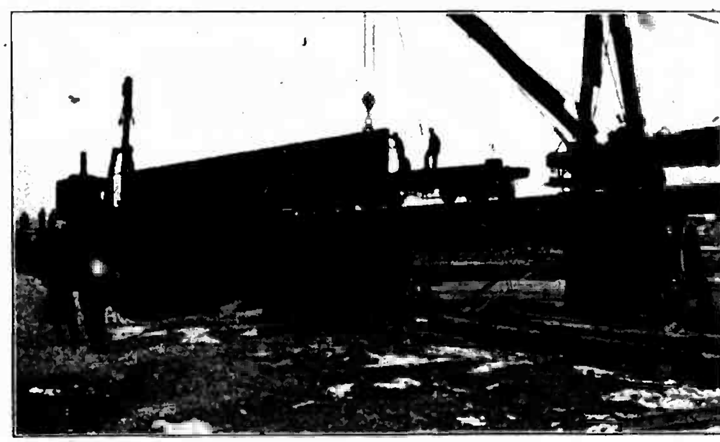
FIRM	Sect. I	Sect. II	I	II
BULLOCK·ELECT.	Thompson, C. E.E. '16	Kruse, R.H. E.E. '16		
	Willson W.R. E.E. '20	Cloud; H.P. E.E. '20		
	Hansen, Dane E.E. '20	Caldwell, A. E.E. '20		
	Schreiber, H. E.E. '20	Herman, Harold E.E. '20		
	Huss, F.W. M.E. '20			
B.&O. R.R.	Demar, A.F. C.E. '20	Hoque, B.E. E.E. '16		
	Chapman, H. C.E. '18	Porter, C.H. C.E. '18		
BELL·TELEPHONE	Stewart, J. Ch.E. '20	Biehl, J.F. E.E. '16		
	Power, D. E.E. '20	Morgan, Wm. E.E. '16		
	Kamphausen, W. E.E. '18	Pinkard, F. E.E. '18		
C.H. & D. R.R.	West, Herbert C.E. '20			
	Elmore, P.W. C.E. '17	De Ginther, W. C.E. '20		
CITY·TEST·BUREAU	Peck, F.W. M.E. '18	Herfinger, H.Y. Ch.E. '17		
PHILIP-CAREY	Hicks, Hobart E.E. '20			
	Hayes, W.L. Ch.E. '16	Taylor, H. Ch.E. '16		
	Ford, Jr. C.W. M.E. '17	Bagle, W. Ch.E. '16		
	Holz, R. C.E. '17	Baker, J.L. Ch.E. '16		

A partial list of industries reached by the cooperative system indicates something of the variety of experience which can be utilized in this way. Among the cooperating firms are four railroads, a traction company, a telephone company, a gas and electric company, rolling mills, structural iron works, consulting engineers, city, county, and Federal engineering departments, excavation and building contractors, and manufacturers of machine tools, automobiles, elevators, engines, bicycles and motorcycles, cash registers, fire engines, printing machinery, paper-making machinery, adding machines, roofing, ink, and soap.

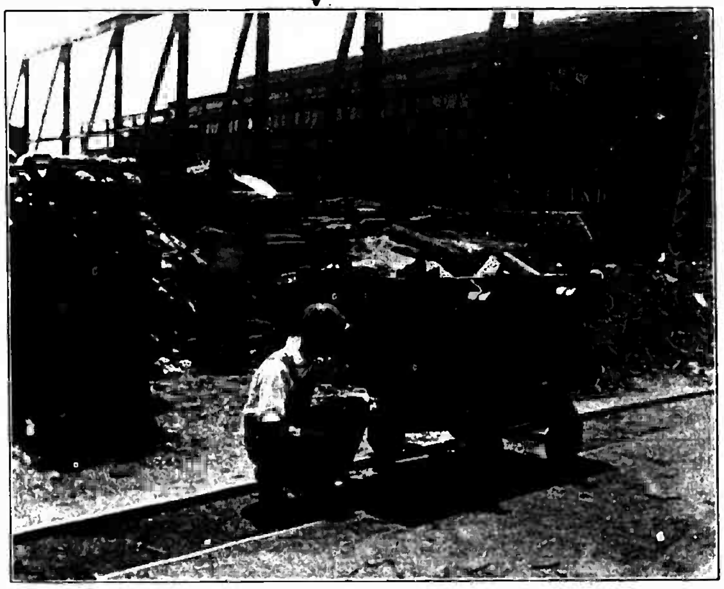


MAIN LABORATORY, ENGINEERING COLLEGE, UNIVERSITY OF CINCINNATI.

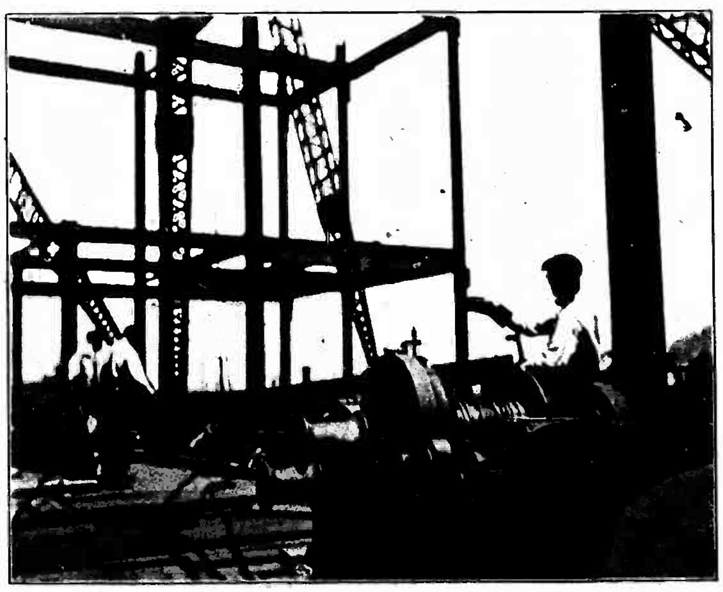
A. TRACK REPAIR WORK, PENNSYLVANIA RAILROAD.



B. BRIDGE CONSTRUCTION, PENNSYLVANIA RAILROAD.

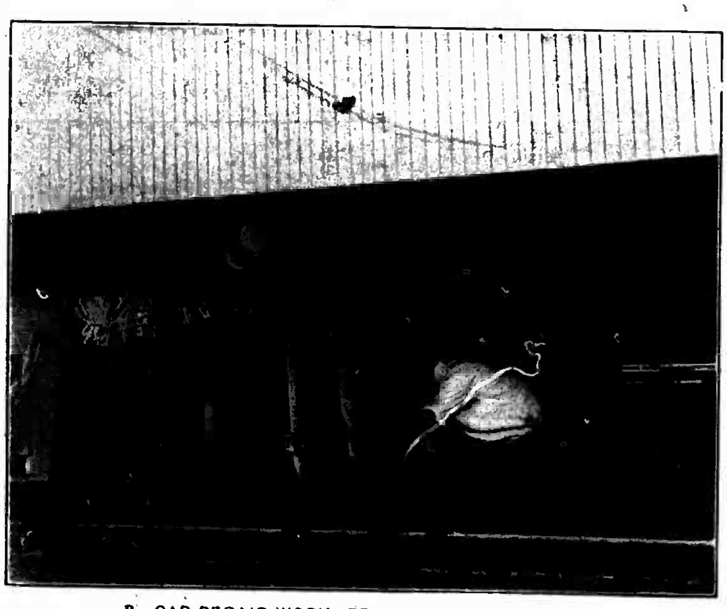


A. FOUNDRY WORK. WEIGHING UP THE CHARGE.



B. STEEL CONSTRUCTION WORK.

A. REPAIR OF CAR-LIGHTING EQUIPMENT, PENNSYLVANIA RAILROAD.



B. CAR REPAIR WORK, PENNSYLVANIA RAILROAD.

SHOP SCHEDULE.

A complete list of cooperating firms, students employed, alternates, and other shop information is kept in the faculty room. In the typical section of a shop schedule given on page 16, the pairs of names under each firm are those of alternating students, who are designated as belonging to Section I and Section II, respectively. The spaces

SCHEDULE OF SHOP VISITS

FIRM	SECT. 1.	SECT. 2.	1.	2.	
Period Ending	Oct. 2 '15	Oct. 16 '15			
American Roll Mills Co.	Burns 9-29-15				
American Tool Wks.	Jenkins 9-30-15	Burns 10-12-15			
Ault-Wiborg Comp.	Jones 9-17-15 Burns 9-17-15				
Ahrens Fox Co.	Faig 9-27-15	Faig 10-7-15			
B. & O.	Braune 9-30-15				
Big Four	Braune 9-24-15 Burns 9-24-15	Burns 10-6-15 Braune 10-6-15			
Bell Telephone Co.	Wilson 9-18-15				
Brownell Co.	Faig 9-16-15				
Bullock Elec. Co.	Wilson 9-22-15	Wilson 10-10-15			
Cin'ti Milling Mach. Co.	Faig 9-23-15 Burns 9-23-15	Burns 10-14-15			
Cin'ti Traction Co.	Wilson 9-30-15				

marked with a single cross line indicate that no alternate is provided, and that none is desired. The space marked with double cross lines indicates that an alternate is wanted. Detachable cards are used, in order that the list may be easily revised and kept up to date.

SHOP VISITS.

The above schedule from the current records is typical of the shop visits made by various instructors in the technical departments. These visits are made at regular intervals on an established schedule

COORDINATION OF SCHOOL AND SHOPWORK.

Shop records.—With provision thus made for handling the business problems of the course, the work of the department of coordination, instead of dealing, as at first, with commercial problems, was developed from a purely pedagogical standpoint. The department became a clearing house for the practical applications of engineering theory and for the shop records of individual students. These records, kept on cards designed for the purpose, are filled out every two weeks, and a graphical summary of the data from the cards is made each semester. Examples of shop records for the short and the long periods are given below. By reference to the statements of experience, the department of coordination checks the thoroughness of a student's practical training and of his collateral instruction.

At the beginning of each school period the student enters on the semester card his experience for the shop period (two weeks) just closed.

WORK RECORD CARD.

NAME. *Binns, H. Stanley*	CLASS OF 1915.		SCHOOL YEAR ENDING AUGUST, 1915.	SEMESTER I.
FIRM. *Cincinnati Milling Machine Co.*				
WEEK ENDING	HOURS WORKED.	HOURS LOST.	DEP'T.	NATURE OF WORK DONE.
Sept. 19	*49½*	*0*	*Off.*	*Estimating milling operations.*
Oct. 10	*49½*	*0*	"	" " "
" *17*	*49½*	*0*	"	" " "
Nov. 7	*49½*	*0*	"	" " "
" *14*	*49½*	*0*	"	" " "
Dec. 5	*40½*	*9 ex.*	*Plan.*	*Time study work—Milling machine.*
" *12*	*49½*	*0*	"	" " " " "
Jan. 2	*49½*	*0*	"	" " " " "
" *9*	*49½*	*0*	"	" " " " "
" *30*	*49½*	*0*	"	*Working up time-study curves.*
TOTAL.	*486*	*9*	DEGREE, *M. E.*	ENTERED SEPT., 1910 — WAGES *Feb. 1, 1914*, RATE *.22*. RAISED *Nov. 14, 1914*, RATE *.24*.

On the sheet marked "Record of Cooperative Work" the records from each man's semester cards are compiled in a statement which, when completed, shows graphically his practical experience for the entire five years. The chief types of work are listed on different sheets, headed M. E., C. E., and so on, for the several departments. As shown in the record below, provision is also made for the statement of a man's previous experience and of his wages throughout the course.

COOPERATIVE EMPLOYERS.

I Cinti. Mill. Mach. Co.
II
III
IV
V
VI
VII
VIII
IX
X

FORM

NAME

Record ... vio

Probat

FIRM NUMBER

June 1.

COOPERATIVE WORK.
(DEPT. OF M. E.)

1. Office: Sales dept.
2. Cost dept.
3. Stock dept.
4. Estimating mill. op.
5. Planning dept.
6. ....
7. Drafting room: Gen'l design.
8. Tool and jig design.
9. Detailing.
10. Tracing.
11. ....
12. Machine shop: Misc. work.
13. Experimental work.
14. Die making.
15. Tool and jig making.
16. Testing finished machine.
17. Floor assembling.
18. Floor repair.
19. Misc. floor work.
20. Vise and bench work.
21. Reamer bench.
22. Lathe, engine.
23. Lathe, turret.
24. Screw mach., auto.
25. Screw mach., hand.
26. Grinder.
27. Cutter grinder.
28. Planer.
29. Shaper.
30. Boring mill.
31. Gear cutter.
32. Milling machine.
33. Thread miller.
34. Key seater.
35. Radial drill.
36. Upright drill.
37. Tool-room attendant.
38. Timekeeper.
39. Inspecting parts.
40. Millwright work.
41. Polishing lathe.
42. ....
43. Hardening dept.
44. Forge shop.
45. Boiler shop.
46. Sheet-metal shop.
47. Structural steel shop.
48. Garage.
49. Car barn.
50. ....
51. Roundhouse.
52. ....
53. Power plant: Gen'l rep.
54. Oiler.
55. Fireman.
56. Pipe fitting.
57. ....
58. ....
59. Pattern shop.
60. Foundry: Iron; st.; br.
61. Molding: Fl.; bch.
62. Machine molding.
63. Cupola.
64. ....
65. ....
66. ....

Record of wages received:

30
25
20
15
10

	Cents per hour.
	Dollars per week.

[1]For a detailed account of work during t

...M No. 79.

RECORD OF COOPERATIVE WORK.[1]

UNIVERSITY OF CINCINNATI,
DEPARTMENT OF MECHANICAL ENGINEERING,

DEPT. OF M. E.

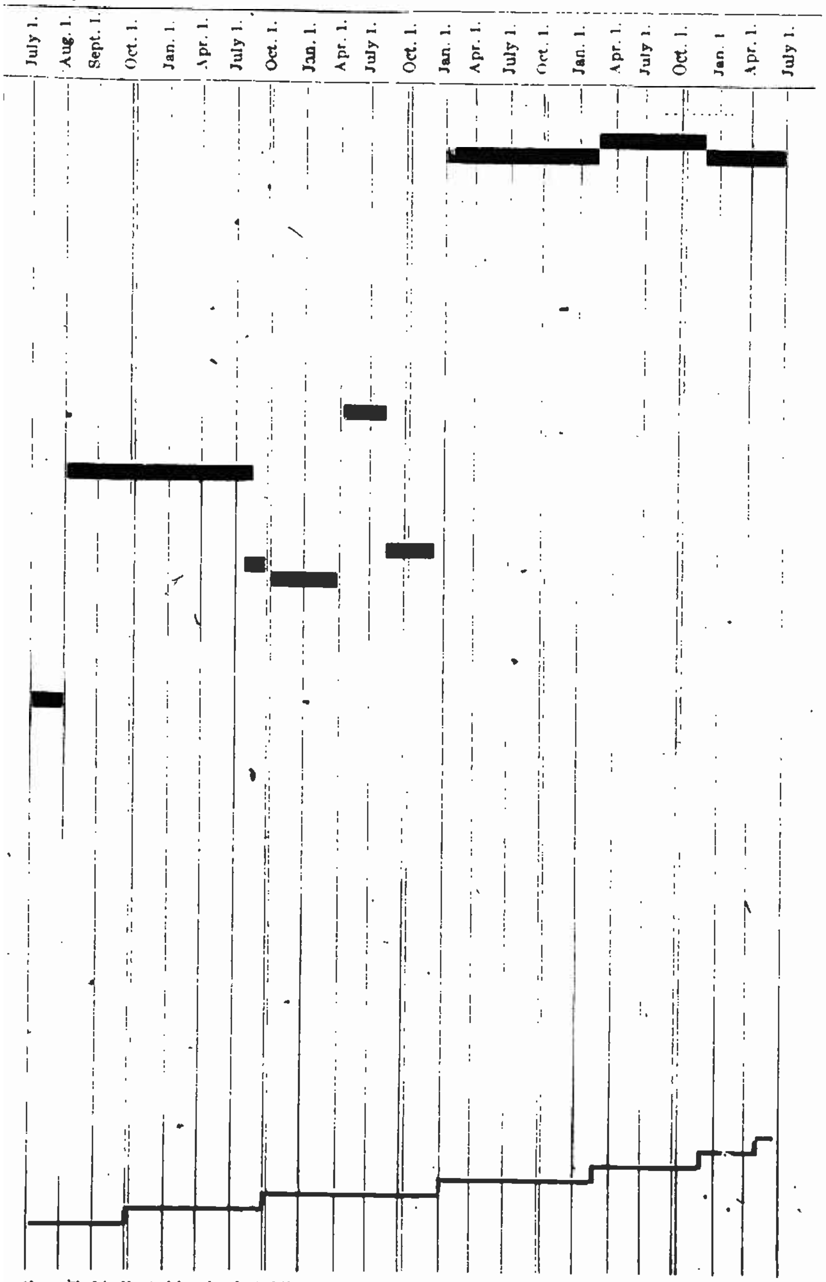
RESIDENT.
NON-RES.

...ME: *Binns, H. Stanley* DEGREE: *M. E.* CLASS OF *1915*

...cord of any pre-...vious work.	FIRMS	NATURE OF WORK	No. Mos.
	Binns Milling Co.	*General work around flour mill.*	*12*

...bation.	Year one.	Year two.	Year three.	Year four.	Year five.
1910	1911	1912	1913	1914	1915

...BER. 1



...ng the period indicated by the dotted line, see shop record card on page 18.

Instruction sheets.—A later undertaking by the department of coordination was an analysis of shop practice and the formulation of a set of instructions for each type of work. Appendix B contains excerpts from typical sets of instructions. Syllabi of this kind have been prepared for the principal types of work done by students, and additional sets of instructions are made out from time to time as they are needed.

Since the educational value of a machine or a piece of work is proportional to its complexity, or the amount of thought that has gone into it, the syllabi naturally vary in length and in disciplinary importance. It would be incorrect, however, to assume that the student may profitably spend upon each type of work only the amount of time required to master a set of instructions and problems dealing with a particular machine. It is often found worth while for him to remain longer, in order to become familiar with the arrangement and operation of the department in which his special work is included. Thus, because he can study the surrounding machinery, a student may be justified in operating a drill press longer than would be necessary for him to learn its simple mechanism. In a foundry his training need not be restricted to molding, core making, and pattern making. From the patterns and castings he will learn much about machine design, and he will naturally receive many ideas concerning foundry management. Timekeeping, inspecting, and other kinds of work which in themselves are comparatively simple may likewise afford such opportunities for observation as to make them very desirable from the standpoint of practical instruction and coordination. In all coordination outlines, emphasis is placed upon the incidental training which accompanies the various types of work.

Special kinds of work arise from time to time which can not be anticipated by any syllabus, but which may have greater instructional value than the regular tasks. For example, during the Ohio floods of 1913 some of the students in the civil engineering department suddenly found themselves face to face with problems and responsibilities far beyond their experience. They "made good," and incidentally learned many important things about railroad construction. At this time a similar opportunity came to the senior class in electrical engineering. The lighting system at Hamilton, Ohio, had been completely disorganized, and much of the equipment had been badly damaged by the flood. The students spent a week making repairs and, of course, working out the solutions for many practical problems in electrical engineering.

Inspection trips.—Apart from the varied forms of shop experience, an opportunity to learn by observation is provided by the inspection trips, which are made by all students during the school periods. These visits to representative engineering industries are carefully planned and graded with reference to the student's course and his progress. During the first year the trips include only the larger and more general phases of industry, and are made under the direction of the department of coordination. A typical list of plants visited in the first year is as follows:

1. The Cincinnati Water Works (pumping and filtration plants).
2. The Andrews Steel Co. (rolling mills).
3. The Jarecki Chemical Co. (sulphuric acid, commercial fertilizers, and alum).
4. The Hopple Street Viaduct (under construction).
5. The Cincinnati Milling Machine Co. (machine tools).
6. The Bullock Electrical Co. (electrical machinery).

Each trip is preceded by lectures on the type of plant to be visited, its layout, and its special engineering features. Wherever possible the trip is brought into relation with the student's regular class work. For example, the visit to the Jarecki Chemical Co.'s plant is made in connection with the discussion of the manufacture of sulphuric acid in the class in chemistry. A report of from 5 to 10 pages, including a sketch, is required of each student. All reports are written under the joint direction of the department of English and the technical department concerned.[1] The inspection trips made by upper-class men differ mainly in that they deal with more specific phases of industry, and that they are in charge of the several engineering departments.

Production engineering.—In the last two years of the course, special work is given in production engineering. A study is made of such phases of industry as management, routing of work, cost systems, location, organization, and operation of factories, contracts, specifications, and wage systems. In this course, which is given by the department of coordination, the student's experience during the first three years is utilized in giving him standards and methods of management.

REVISION OF THE COURSE.

Length and distribution of time.—While the various changes were under way in the shopwork and in coordination, the courses in theory were undergoing a corresponding reorganization. The change from a six-year to a five-year plan involved a consideration of the time which should be allotted to each subject, and this in turn raised the fundamental question of what the subject was intended to accomplish. In other words, why was it included in preference to other studies not in the curriculum? To satisfy themselves on this point, instructors began to analyze their courses and test the value of the subject matter in a scheme of engineering education. This analysis

[1] See p. 43.

resulted in the elimination of a great deal of superfluous descriptive material and in a new emphasis on the fundamentals.

Changes in the curriculum.—Further criticism of the different courses was carried on by the faculty as a whole. In the weekly meetings an investigation was made of the object of each branch of study and of its relation to other subjects and to the entire engineering course. Reports of committees were followed by general discussion, with the result that every part of the curriculum which had no demonstrable value was omitted, new material was introduced, and the more important parts were strengthened. The ground was staked off anew, and many cases, both of overlapping and of deficiency, were remedied.

In order to check the related portions of prerequisite and advanced courses, the following form was designed for reporting deficiencies:

> Name...... *J. E. Jones.* Date...... *1-3-15.*
>
> To Dept. of *Math.*, from Dept. *E. E.*
> Deficiencies: *Unable to perform integration to obtain average and effective e. m. f. for a sine wave.*
>
> Remarks: *A discussion of average values by means of integrals would be of service to this department.*
>
> Course *E. E.* ....
> Signature of instructor.

The significance of this report depends naturally upon whether it represents an individual case or that of a number of students. If the former, it provides a reason for invoking the provisional credit rule—that is, to require the student to review the prerequisite subject. If the latter, it indicates to the instructor the need of greater emphasis on the mathematical process in which the deficiency is found to exist. In any case, it fixes the responsibility for the failure of students to have a working knowledge of prerequisite subjects.

The data collected during the analysis of courses were later brought together, and a uniform outline was adopted for the presentation of the object, method, and matter of each course. The outline given below is typical.

UNIVERSITY OF CINCINNATI—COLLEGE OF ENGINEERING. SYLLABUS OF THE COOPERATIVE SYSTEM.[1]

Object.	Method.	Matter.	Mechanism.
TO PROVIDE ENGINEERING TRAINING FROM WHICH THE STUDENT SHALL ACQUIRE: 1. A foundation in the basic principles of science.	1. Instruction in science and mathematics.	1. Chemistry, physics, mathematics, economics, biology, practical engineering projects.	1. Class and laboratory work; coordination with practical experience.
2. Ability to use these principles in practice.	2. Gradual and natural advancement in practical work which uses these principles.	2. An organized sequence in practical work.	2. Cooperation with commercial concerns doing engineering work.
	Concurrent training in the theory and practice of engineering.	An organized sequence in science.	Alternate periods spent by two groups of students at school and at practical work.
3. An understanding of engineering in general, as well as of one special department.	3. Varied exemplifications of theory in the classroom.	3. Experiences of students in different types of work correlated with theory.	3. Coordinators and students furnish illustrations.
	Organized visits to a variety of engineering industries.	Visits to waterworks, foundries, soap works, etc.	Organized shop visits.
	Contact with fellow students in different kinds of engineering work.		
4. A working knowledge of business forms and processes.	4. Instruction in economics, management, etc. Reports on shop visits; analysis of shop processes.	4. Fundamental principles of economics, systems, forms, contracts, patents in engineering work, etc.	4. Coordination of classroom work with students' experience.
	Practical experience in business forms and procedure.	Reports on organization and operation of waterworks, foundries, soap works, etc.	Practical training organized by coordinators to insure experience in business forms and processes.
		Routing of work in shops, time-keeping, rate-setting, cost-keeping, etc.	
5. A knowledge of men as well as of matter.	5. Personal work with men from laborers up to superintendents or managers.	5. Practical work, from laboring to directing.	5. Prearranged course of practical training.
	Instruction in the basic elements of work.	Fatigue, wage systems, employment methods, sanitation, etc.	
6. Drill and experience in the following essentials:			
a. Doing one's best naturally and as a matter of course.	a. By regulating promotion and pay on practical work.	a. Practical performance; classroom performance.	a. Constant supervision and criticism of student's practical work. Consultations by college officials on advancing students on jobs.

	By maintaining a satisfactory standard in college work.		Internal coordination of college departments; conferences on work of students.
b. Prompt and intelligent obedience to instructions.	*b*. By working under the rules of an industrial organization.	*b*. Practical work under foremen.	*b*. Student is kept at manual labor until he learns to obey orders.
	By learning the reasons why things are done.	Using practical experience in science courses.	Coordination of theory and practice.
		Work syllabi.	Study of work syllabi.
c. Ability to command intelligently and with toleration.	*c*. By gradual rise to positions of responsibility in the cooperating companies.	*c*. Practical jobs of more and more authority and responsibility. Personal experience in hard work.	*c*. Success of student on practical and theoretical work checked by coordinators. Round table discussion in shop management courses.
	By courses dealing with conditions under which men work.	Fatigue, wage systems, employment methods, sanitation, etc.	
d. Accuracy and system.	*d*. By practical work which requires mental and manual accuracy, and which proceeds with a sequential orderliness. By insistence in school on accurate work and orderly methods of presentation.	*d*. Carefully selected jobs. Analyses of shop processes in class.	*d*. Close familiarity with outside work through visits of coordinators. Coordination between departments to maintain standards.
		All college courses.	
e. Ability to write clearly and concisely, and to present technical matter interestingly before an audience.	*e*. By constantly requiring written work under criticism, and by requiring oral presentation of technical matter.	*e*. Reports on shopwork. Reports on shop visits. Laboratory reports. Student engineering society papers and discussions. Class practice under criticism.	*e*. Coordination of English department with other departments in criticizing all written work. Student engineering societies afford practice in oral presentation. Regular class exercises in presenting engineering reports.
7. Ability to meet social requirements easily.			
8. An appreciation of humanity's best achievements.			

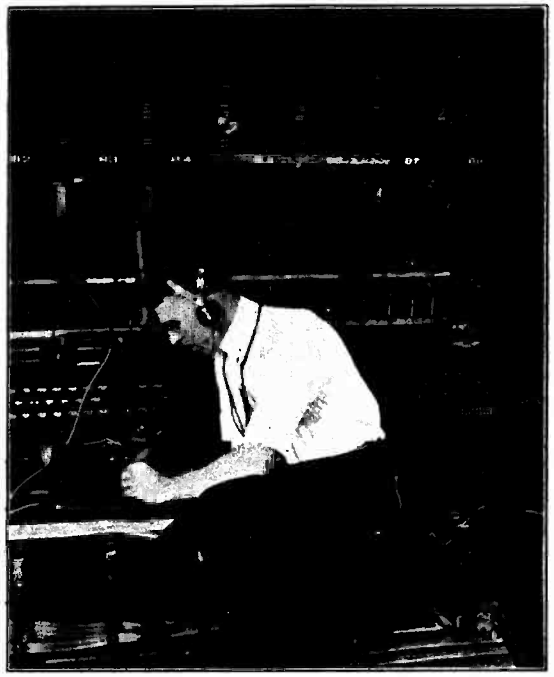
[1] The objects listed in this syllabus, with slight differences in phrasing, were first stated by Dean Schneider, in 1902. The methods suggested in the original paper for accomplishing objects 7 and 8 have not been found feasible without certain features of mechanism obtainable only in colleges like those at West Point and Annapolis. However, new methods, matter, and mechanism for number 8 have been devised to meet the situation as it exists at Cincinnati, and these are now in the experimental stage.

In the outline of the courses in chemistry which follows, the objects given in the first column are those agreed upon as common to all the courses, though in different cases the objects may vary in relative importance. For example, No. 4, which is the main object in English courses, is secondary in a course in chemistry. Methods differ more widely than objects, and manifestly subject matter is or should be entirely different in the various courses. In fact, one of the main reasons for making so extensive a survey of the curriculum was to avoid duplication of subject matter.

SYLLABUS OF COURSE IN CHEMISTRY.

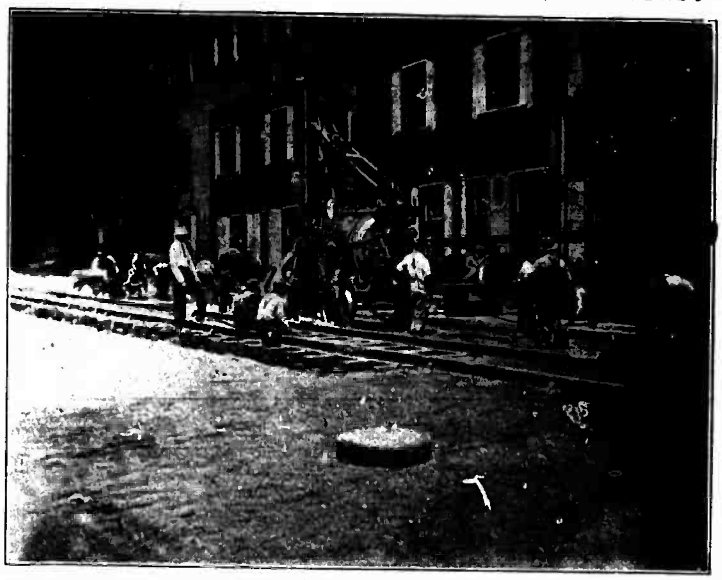
Object.	Method.	Matter.
TO HAVE THE STUDENT ACQUIRE: 1. The fundamentals of the given subject.	1. Lectures experimentally illustrated, covering fundamental theories and laws, and the properties of the principal metals and nonmetals, especially those of industrial interest; occasional recitations with oral and written quizzes; experimentation in the laboratory to parallel the lecture course.	1. Not essentially different from subject matter given in good texts on general chemistry, except that practical applications of chemistry are emphasized; occurrence, properties, and uses of the principal metals and nonmetals; properties useful for identification; fundamental theories and laws.
2. A comprehension of the scientific method as exemplified in—(*a*) accurate observation; (*b*) classification and correlation; (*c*) logical reasoning.	2. Detailed study of groups of elements (e. g., the halogens, the alkali metals), leading to observation of similarities in properties, and subsequent classification into groups; simple problems permitting formulation of hypotheses and establishment of truth or falsity of these by experiment; enunciation of laws after examination of particular cases.	2. As under 1.
3. Mental self-reliance and initiative; *i. e.*, the ability to analyze a scientific problem and devise means of solution.	3. Problem work introduced early into the course and given increasing prominence until the summer term, when it is pursued exclusively; simple problems in synthesis and analysis assigned or suggested by student who proposes the method of attack; does all necessary library reading and carries to completion a process of chemical manufacture—for example, making a pound of baking powder; instructor assumes rôle of critic and interferes as little as possible with course of work.	3. Individual problems in synthesis and analysis of commercially valuable products; ores—identification, valuation, and subsequent working up for useful products—e. g., alum from bauxite, salts of iron, copper, barium, etc., from their ores; products used in laboratory; blue print papers, boiler water, soaps, baking powders, driers, paints, coal, inks, foods, etc.
4. Habits of neatness in student's work, and clear, concise, accurate expression, both oral and written.	4. Written work, in order to be accepted, must meet a prescribed standard of excellence; faulty oral expression corrected.	4. Instruction in the writing of reports and in the arrangement of chemical data; models, specifications, and criticism; given in connection with the department of English.
5. The connection of the given subject with the other subjects in the curriculum and with the profession of engineering.	5. Constant correlation of subject of lectures with practical engineering; e. g., oxidation in connection with generation of power (combustion of coal).	5. Illustrative material for lectures and problems; refers largely to local industries in which the principles under discussion are practically applied.

Because of the numerous changes in distributing and handling the subjects themselves, the reorganization made a much greater change in the cooperative course than is suggested by a comparison of curricula in the earlier and later periods. Omission of certain details, and a change of emphasis on others, constituted the principal features of

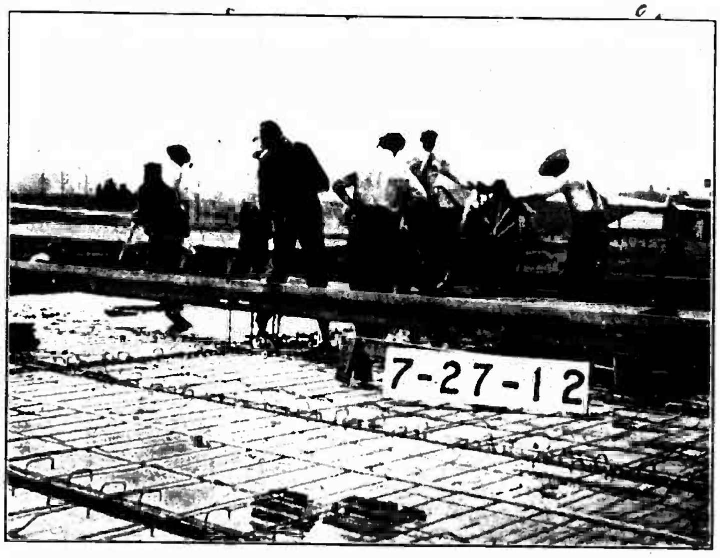


A. TELEPHONE EXCHANGE. "TROUBLE WORK."

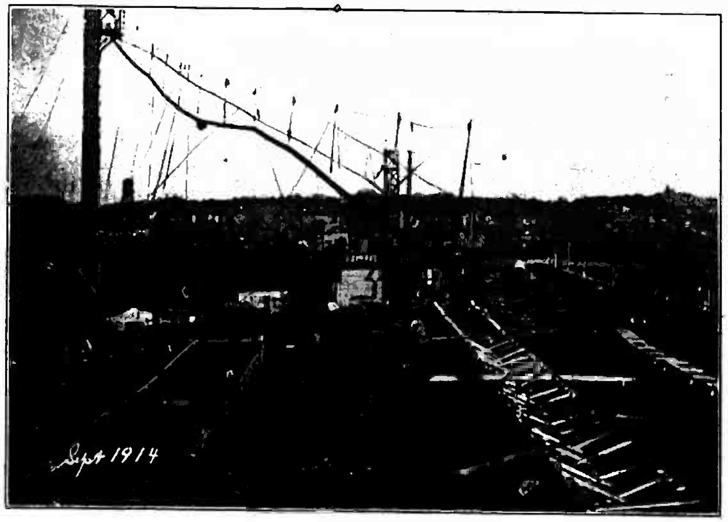
B. TELEPHONE EXCHANGE. REPAIR WORK.



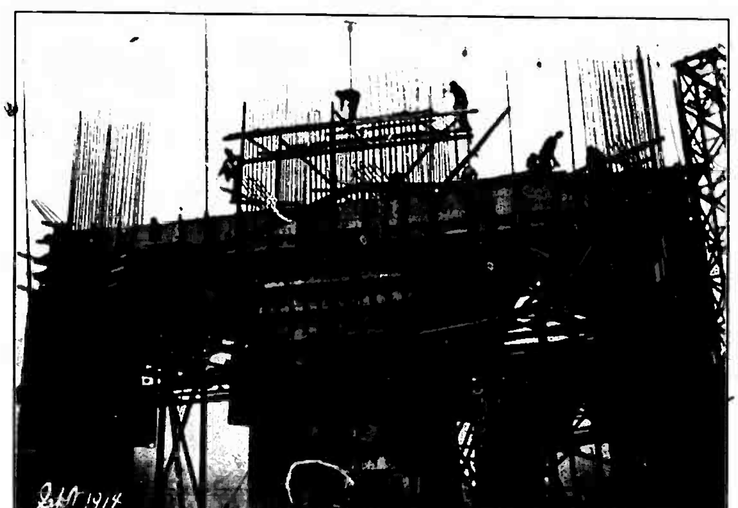
A. COOPERATIVE STUDENT AS INSPECTOR OF STREET REPAIR WORK.



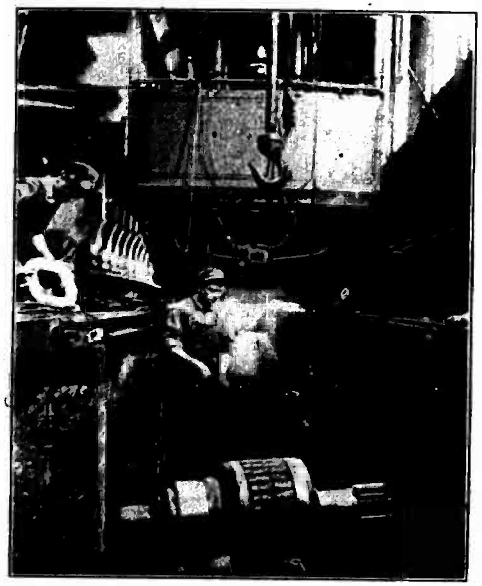
B. COOPERATIVE STUDENT AS INSPECTOR OF BUILDING CONSTRUCTION.



A. REINFORCEMENT FOR CONCRETE VIADUCT, SHOWING METHOD OF POURING CONCRETE.



B. STEEL FRAME FOR PIERS ON CONCRETE VIADUCT.



A. CAR BARN REPAIR WORK. MOTOR REPAIR.

B. GENERATION REPAIR WORK.

the reorganization. Purely descriptive courses were discontinued, and the descriptive matter in all the courses was reduced to a minimum. Much of this material was assigned as incidental reading, to be done during the two weeks when the student was in the shop. In keeping with the underlying theory of the cooperative course, advantage was taken of the reality of first-hand knowledge as against a merely bookish approach. A student who has worked on a lathe, who has drawn it and has explained its construction and operation before a class, requires less reading and certainly less textbook study in order to understand the subject than a student who has only a theoretical knowledge.

By reducing the amount of time given to informational studies, it was possible to give more attention to fundamental subjects than could be given in the regular four-year course. This, too, was in accordance with one of the principal tenets of cooperative education—that the school is primarily a teaching institution, designed to give training that can not easily be obtained through any other agency.

MECHANICAL ENGINEERING—COOPERATIVE PLAN.[1]

COURSES REQUIRED FOR THE DEGREE OF M. E.

Subject.	Course.	Exercises per alternate bi-weekly period.	
		I sem.	II sem.
FIRST YEAR.	FRESHMAN.		
Algebra and trigonometry	Math. 1	6	6
Analytical geometry			
General inorganic chemistry	Ch. E. 1a, 3b	5	5
General inorganic chemistry laboratory	Ch. E. 2a, 4b	3	3
Machine drawing	M. E. 1	3	..... 6 ..
Descriptive geometry	C. E. 1	....	3
Coordination	C. 1	2	2
Elements of engineering	M. E. 4	3	3
English	Eng. 41	1	1
FIRST SUMMER TERM.			
Elements of engineering	M. E. 4	6	....
Problems in industrial chemistry		6	....
Descriptive geometry		5	....
English	Eng. 41	1	....
SECOND YEAR.	SOPHOMORE.		
Differential and integral calculus	Math. 5	6	6
Physics (general)	Physics 1a, 21b	6	6
Experimental physics	Physics 2a, 22b	2	3
Metallurgy	Met. E. 1a	5	....
Metallurgy, laboratory		3	....
English	English 2b	....	5
Drawing	M. E. 9	....	2
Coordination	C. 2	2	2
English	Eng. 42	1	1
SECOND SUMMER TERM.			
Mechanism	M. E. 6	6	....
Drawing and sketching	M. E. 7	7	....
Mechanical laboratory	M. E. 18	4	....
English	Eng. 42	1	....

[1] Extract from the catalogue of the University of Cincinnati.

COURSES REQUIRED FOR THE DEGREE OF M. E.—Continued.

Subject.	Course.	Exercises per alternate bi-weekly period.	
		I sem.	II sem.
THIRD YEAR.	PREJUNIOR.		
Mathematics	Math.	2	....
Steam engineering	M. E. 11	6	6
Physics, laboratory	Physics 13	....	3
Strength of materials	Ap. Math. 2	6	....
Mechanics	Ap. Math. 1	....	6
Mechanical laboratory	M. E. 18	2	2
Power-plant inspection trips	M. E. 16	1	1
Modern languages	....	5	5
English	Eng. 43	1	1
THIRD SUMMER TERM.			
Electrical engineering	....	7	....
Graphics	M. E. 17	5	....
Steam engineering	M. E. 11	5	....
English	Eng. 43	1	....
FOURTH YEAR.	JUNIOR.		
Modern language	....	5	5
Machine design	M. E. 13	5	....
Machine design	M. E. 14, 19	4	4
Electrical machinery	E. E. 1, 9	6	6
Electrical laboratory	E. E. 5	2	2
Coordination	C. 8	3	3
Hydraulic machinery	M. E. 27	....	5
English	Eng. 44	1	1
FOURTH SUMMER TERM.			
Engineering design	M. E. 28	12	....
Experimental engineering	M. E. 25	5	....
English	Eng. 44	1	....
FIFTH YEAR.	SENIOR.		
Gas engineering	M. E. 23	5	....
Machine-shop tools	M. E. 15	....	5
Experimental engineering	M. E. 25	2	....
Economics	....	5	5
Thermodynamics	M. E. 21	2	5
Engineering design	M. E. 28	4	2
Production engineering	C. 9	5	....
Thesis	....	....	5
English	Eng. 45	1	1

The change of emphasis brought about by the reorganization was reflected chiefly in the insistence upon fundamentals common to all branches of engineering and in the stress placed upon the connection between affiliated subjects. The first three years of civil, mechanical, electrical, and other engineering courses were made essentially the same in theory. Thus, if a student discovered during the first three years of practical experience that he was better suited to a different kind of work, he could easily change his course; for, so far, he would have been studying simply *engineering*. On the other hand, if he showed sufficient aptitude in one branch of engineering to succeed in three years of practical work, he had earned the right to specialize in the theory of that branch during the last two years of his course.

The question of establishing close relations and effective cooperation between affiliated departments was largely an administrative one. Mention has already been made of the connection which was established between prerequisite and advanced studies. In the same way, it was found that several pairs of courses could be made to work together. For example, in part of the work English composition instead of being given as an entirely separate course was connected with courses in coordination, chemistry, mechanical, electrical, and metallurgical laboratory, and other courses in which written work was required.[1] Since it was in these courses that the principles of composition were being applied, this arrangement provided numerous subjects for practical themes and at the same time insured more satisfactory writing in the technical course. The double check upon subject matter and composition resulted in a marked improvement in all written work. Similar forms of what may be called internal cooperation were worked out between other departments in which reciprocal relations of the sort proved advantageous. Because of the compactness of the faculty organization and the spirit of cooperation between instructors, the personal equation has affected these combination courses only in the most favorable way.

SELECTION OF MEN.

Because the selection of men is one of the essential elements of the cooperative course, investigations were carried on from the beginning in order to discover a possible means of determining in advance the fitness of a student for a particular type of work. The various methods examined, and the results, are given in a lecture delivered by Dean Schneider to the students of the New York Edison Co.'s Commercial School, January 20, 1915. The following extracts serve to indicate the way in which the problem of selection was approached. The only conclusions which were at all satisfactory were reached by the old-fashioned plan of trying a man on the job, combined with an analysis of successes and failures, in terms of the major characteristics of the men and the chief requirements of the jobs. To quote from the lecture:

> We found that different methods were proposed and that certain principles were held to be true which had a bearing on the subject. Our investigation was then directed to learning upon which of these methods we could rely and what usable conclusions could be drawn from accepted principles. We found the following proposed methods and principles:
>
> 1. A chart of boy epochs indicated that at least a certain group of psychologists and philosophers hold to a theory that a boy from infancy to about the age of 21 years reproduces in periods the history of the human race.
> 2. A group in the scientific management field affirmed that an examination of physical characteristics, such as the shape of the fingers and shape of the head, disclosed aptitudes and abilities.
> 3. A school of experimental psychologists asserted that the methods of their science indicated characteristics or aptitudes of individuals.
> 4. There was also the old-fashioned plan of trying a man on the job without any previous examination of any kind.

[1] See p. 43.

Of these methods, the first was interesting, especially as an analysis of a student's actions, but it offered no practical test for the selection of men. The second was found upon examination to be undesirable. The third was made the subject of a series of tests, in which upper-class men were examined, and the deductions of experimental psychology were compared with the known abilities of the students. The results of this investigation showed that the psychological method is not yet trustworthy as a basis for vocational guidance.

The careful examination of many cases under the fourth method, together with an analysis of work in general, revealed the following facts:

THE MAJOR CHARACTERISTICS.

(a) In many occupations physical strength is an essential; for example, in draying, stone masonry, and baggage handling. In others it is not; for example, in bookkeeping, telephone installing, and piano tuning. Mankind ranges from the almost helpless cripple to the physical giant. We therefore have the two characteristics, physical strength and physical weakness.

(b) I have in mind a number of our students who were utter failures at all kinds of work requiring manual dexterity, but who maintained uniformly good grades in all their school work. Their efficiency was all head efficiency. There have been a number also who were hopeless in all their university work, but whose hands acquired skill easily. Their efficiency was all hand efficiency.

The first type might make good designers, inspectors, executives, or writers, but, unlike the second type, would drag out hopeless existences as machinists, molders, masons, or piano makers. Of course most of our students possess both efficiencies. Our experience has taught us that some men are mental and some are manual, while some are both.

(c) There is a type of man who wants to get on the same car every morning, get off at the same corner, go to the same shop, ring up at the same clock, stow his lunch in the same locker, go to the same machine, and do the same class of work day after day. Another type of man would go crazy under this routine; he wants to move about, meet new people, and see and do new things. The first is settled; the second is roving. The first might make a good man for a shop manufacturing a standard product; the second might make a good railroad man or a good outdoor carpenter.

(d) There are two broad characteristics which are easily discoverable even in first interviews, the indoor and the outdoor. When a blizzard is raging, the first type likes to hear the roar of the wind because it heightens his sense of protection indoors and emphasizes the coziness of his fireplace, while the other wants to go out and fight his way against the storm. When the rigors of outdoor railroad and construction work are vividly pictured to these two types of young men, one's eyes will light up and his muscles get tense; the other will compact himself as if for shelter.

(e) We have found two characteristics which are quickly brought out in practical work, but which are not so easily discernible in school work. Some young men naturally assume responsibility; others just as naturally evade it. It is a well-known fact to all superintendents that the most productive workmen often make inefficient foremen, while an inferior producer often makes a good foreman. One man is directive, the other is dependent.

(f) There are two characteristics which are sometimes confused with those just stated, but which are essentially distinct. For example, we had two students in a large shop working in the planning department; one was fertile in suggestions, but the other usually put them into effect. The first was original; the second was directive.

The man who is original may make a good designer, but unless he is also directive he makes a poor superintendent; he may be a good window dresser, but not a department-store manager, a writer but not a publisher, an inventor but not a manufacturer, a reformer but not a mayor. A partnership in which one man is directive and another original is usually successful. Of course, one person may possess both characteristics.

Then there is the man who does only what he is told to do and exactly as he is told to do it. He is imitative. He would dress every window like every other window. He might make a successful milk-wagon driver, since he would have a fixed route and a bottle of uniform size to deliver; but he would probably make an indifferent drayman, since he would not have a fixed route, and originality (or ingenuity) would be needed to load and unload unwieldy boxes and barrels under adverse conditions. He might make a good machine molder, but not a good floor molder; he would probably be successful and happy at a punch press, but not in a tool room.

(*g*) Then there are the two types mentioned before, one of which likes to fuss with an intricate bit of mechanism, while the other wants the task of big dimensions—the watchmaker, the engraver, the inlayer, the painter of miniatures, on the one hand; the bridge builder, the steel-mill worker, the train dispatcher, the circus man on the other. One has small scope; the other large scope.

(*h*) Some men can easily adapt themselves to any environment, while others act the same under almost any circumstances. One takes the local color like a chameleon; the other is always the same monochrome. One is adaptable, the other self-centered; one a salesman, the other a statistician.

(*i*) There is a distinct type which thinks and then does, in contrast to which there is the type which does and then thinks. One is deliberate, the other impulsive. The northern races are usually deliberate, the southern impulsive; one controls its passions, the other is frequently controlled by them. An army of cool-headed officers and hot-headed soldiers is a highly effective machine, but in the civilian walks of life, the impulsive characteristic is negative, that is to say, there seems to be no occupation in which it is a requisite. There are many vocations, however, in which a man must be deliberate.

(*j*) Our cooperation with a piano-building factory made it necessary to secure men who had a native musical ability—a strong tonal sense. It was found that this was a requisite for success in the higher positions; hence, the music sense is included in the list given below. Obviously the music sense is necessary to the musician, to the violin maker, and to the piano tuner. It should be noted in passing that this is only one of the characteristics needed for the violin maker. He must also be settled, manually accurate, and "indoor." But the piano tuner must be roving.

(*k*) Similarly our cooperation with the chemical industries, particularly the ink and paint industries, showed us the necessity of selecting men who possessed strongly the basic characteristic of color sense. It is obvious that this characteristic is necessary also in other occupations, such as house furnishing, window dressing, painting and decorating, and theatrical staging.

(*l*) We learn quickly that some men have manual accuracy and others manual inaccuracy. Where manual inaccuracy is inherent it is well-nigh impossible to correct it; but where accuracy is inherent and the man is inaccurate through habit, the defect can be remedied.

(*m*) Similarly we have the two elements—mental accuracy and mental inaccuracy. The former has much the same meaning as the word logical, and the latter as the word illogical.

(*n*) Certain men are concentrative mentally; they bring all the light they possess to focus on the subject under consideration; they are mentally centripetal. On the other hand, we find men who are mentally centrifugal and who wander from the subject under consideration or flit from one subject to another; they are diffuse.

(*o*) Some men go to pieces in an emergency, whereas, if they were given time to consider the situation, they would hold together and act wisely. They possess slow mental coordination. The emergency man must possess rapid mental coordination. The latter is necessary for success in the baseball player, the locomotive engineer, the motorman, and the surgeon. The former is usually typical of the philosopher, the jurist, and the research scientist.

(*p*) One often hears it said of a man that he has no push, or that he lacks determination, backbone, grit, sand; other men are said to possess these qualities. The first we call static, which means to cause to stand still, and the second dynamic, which means to cause to move. It should be noted that the noisy man is not always a dynamic man—on the contrary, he is frequently static; while the quiet man is very frequently dynamic.

The list then reads:

(*a*) Physical strength
Physical weakness
(*b*) Mental
Manual
(*c*) Settled
Roving
(*d*) Indoor
Outdoor
(*e*) Directive
Dependent
(*f*) Original (creative)
Imitative
(*g*) Small scope
Large scope
(*h*) Adaptable
Self-centered
(*i*) Deliberate
Impulsive
(*j*) Music sense
(*k*) Color sense
(*l*) Manual accuracy
Manual inaccuracy
(*m*) Mental accuracy (logic)
Mental inaccuracy
(*n*) Concentration (mental focus)
Diffusion
(*o*) Rapid mental coordination
Slow mental coordination
(*p*) Dynamic
Static

The method is not scientific in the usual sense of the word; its principal virtue is that it works every day better than any other system we have investigated. It is unscientific because it rests on the judgments of men, and, as we know, mental standards vary; but it should be noted that the facts upon which the judgment is predicated are beyond question, since a student's efficiency in practical work is determinable.

Now, a job can usually be defined broadly by the major characteristics needed for success on it. Thus a bridge-erection job needs an outdoor, roving, directive, original, dynamic man; a punch-press job needs an indoor, settled, dependent, imitative, static man. If a student is successful on a job, it is assumed he possesses the characteristics which the job requires; if he is not, an analysis is made to ascertain which of the characteristics he lacks, and it is concluded that he probably has the opposites of the lacking ones. So in time over a range of jobs, a student shows certain characteristics and a lack of certain others. Upon a knowledge of him obtained in this way we safely "guarantee" upper classmen for more responsible jobs. The method is crude, but it is the best we have found.

The conclusions so far drawn from our experience with about one thousand mature students in school work and practical work are as follows:

1. A worker's failure is as significant as his success, and should be analyzed to indicate a new and fitting job.
2. The characteristics developed by analysis of many successes and failures furnish a basis for placement which works better than any plan we know.
3. The method is crude and unscientific; it requires a period of time much greater than other methods proposed, but it insures a reliable verdict.

NECESSITY FOR CHANGES IN THE COOPERATIVE COURSE.

The changes noted in this section include the principal developments which have thus far been made in the cooperative course in engineering. Because of their gradual growth and the tests which have been given them since their adoption, it is probable that most of these changes will stand. No one will contend, however—least of all, those who are responsible for the course—that these developments represent perfection. It is to be expected that engineering courses in all colleges will have to be revised from time to time in order to meet the demands of a growing profession. Besides having its part in this and other general phases of educational progress, the cooperative course is subject to amendment for reasons peculiar to its nature. An educational system that is organic enough and human enough to maintain a vital connection with industry must of necessity grow and change. However firmly established the general principles of the system may be, the actual operation of the course, linked as it is with conditions of life and work, will continue to open up new problems and new possibilities.

IV. OTHER APPLICATIONS OF THE COOPERATIVE PLAN.

Although the college of engineering at the University of Cincinnati has furnished the most conspicuous example of cooperative education, it is by no means the only school, or the only type or grade of school, in which the plan has proved successful. The validity of the general principle has been established by the experience of a dozen or more institutions, including both engineering colleges and secondary schools, which have adopted some form of cooperation. Much discussion has been carried on, relative to the extension of the cooperative plan to other branches of education, and it is safe to predict that before long several important experiments in this direction will be undertaken. This is not the place for a detailed description of cooperative courses in other institutions, though an account of the system is hardly complete without some reference to the various fields of education to which cooperation has been or may be extended. But first, by way of recapitulation, it will be well to summarize the chief attributes of the term "cooperative education" as it has been used in this bulletin.

DEFINITION OF COOPERATIVE EDUCATION.

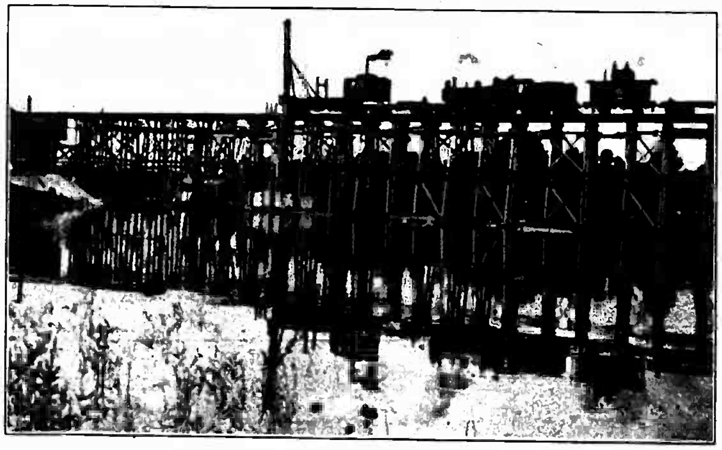
By "cooperative system" is meant the coördination of theoretical and practical training in a progressive educational program. Since the agency which furnishes the practical experience is always some branch of actual industry, the reciprocal relation between school and shop permits the fullest possible utilization, for educational purposes, of equipment used in commercial production. Obviously, the arrangement of alternating periods is a mere administrative detail. From the employer's point of view, the most important elements of the cooperative plan are: First, the selection of workers; and, second, the awakening of an enlightened interest in their work through coordinated instruction.

From the standpoint of the school and the student, the most important feature of cooperative education is the *realization* of theory through its practical applications. In a very literal sense the studies in the curriculum become "applied subjects." In the use of the word "cooperative," emphasis is placed not only on the kind of training given, but also on the relation between school and industry, and on the method of bringing them together.

In recent discussions of educational matters, there has sometimes been a tendency to associate with the cooperative plan phases of education which clearly are not included in the foregoing description. In fairness to other methods and philosophies of education as well as to the cooperative system, the several methods should be sharply differentiated. In the study of a system, not isolated features, but a collection of attributes, and the object and method of their combination, should be considered. Manual training, the Gary plan, trade schools, continuation schools, apprentice systems, and the more legitimate forms of vocational and "earn-while-you-learn" schools may have some things in common with the cooperative plan, and with each other; but in underlying theory and method they are different. Each should be judged according to its own theory, standards, methods, and results; and its place in the general scheme of education should be determined accordingly.

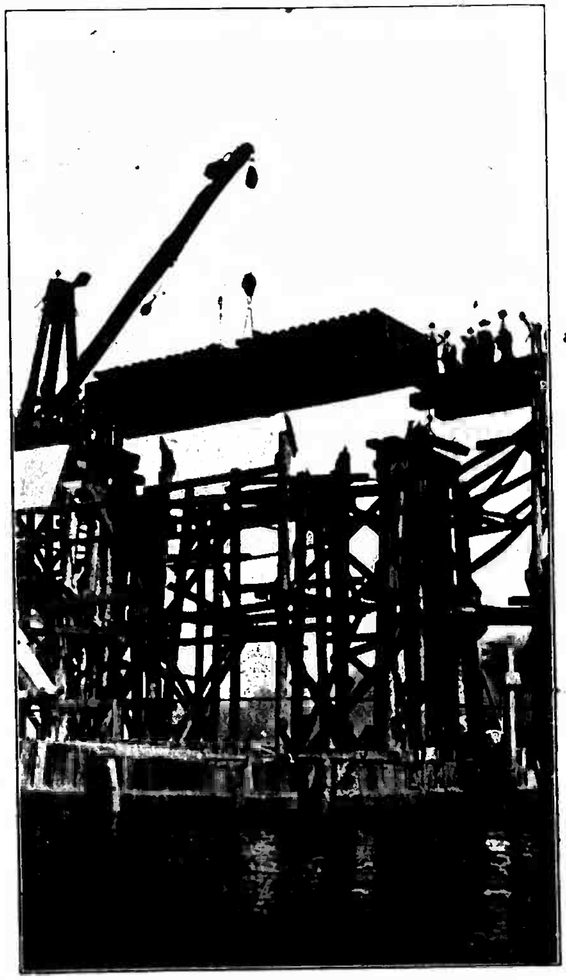
COOPERATION IN HIGH SCHOOLS.

In a number of high schools the cooperative plan has been adopted and courses have been operated successfully under widely varying conditions. At Fitchburg, Mass., for example, an arrangement exists whereby high-school students, after spending one year wholly in school, work during alternate weeks as apprentice machinists, pattern makers, saw makers, draftsmen, molders, tinsmiths, printers, or textile workers. The instruction which they receive at school is coordinated with their practical work. The cooperative principle is similarly applied in the York (Pa.) High School, where the students work in machine shops, foundries, automobile and carriage works, and in the cabinetmaking department of a piano factory. Recently cooperative courses have been introduced into several high schools in New York City. At present cooperation is being carried on with mail-order houses, department stores, machine shops, railroads, automobile factories, printing offices, electric light and power com-

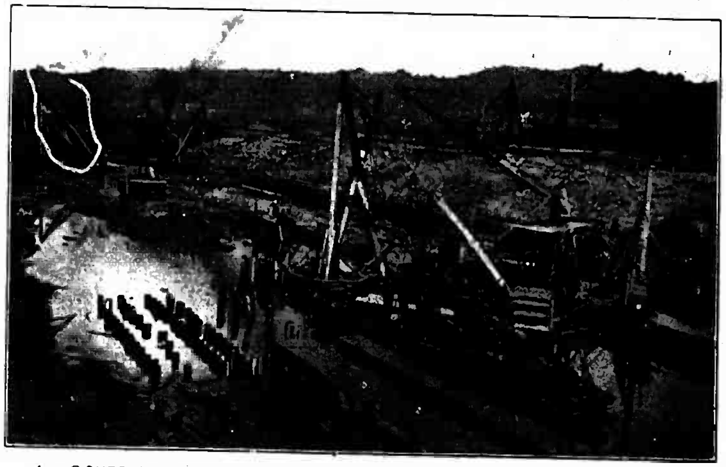


A. PILE DRIVING. BIG FOUR RAILROAD.

B. LAYOUT OF PLANT FOR CONSTRUCTION OF GOVERNMENT DAM, OHIO RIVER.

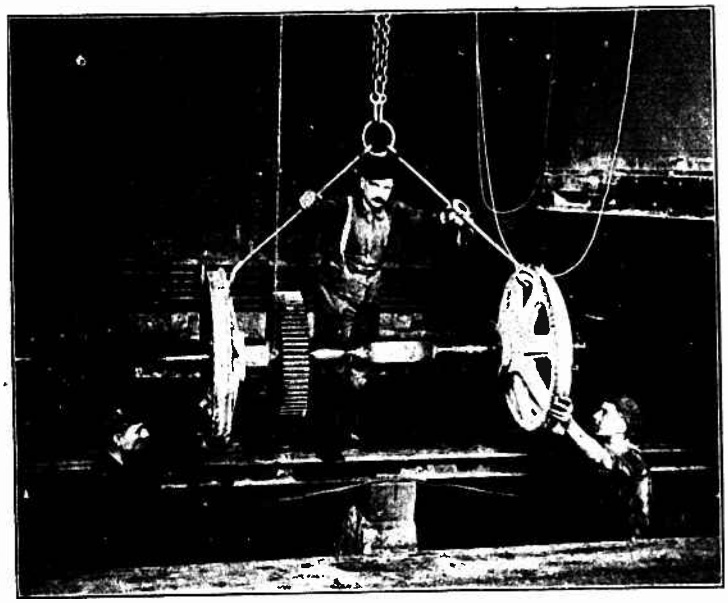


BRIDGE CONSTRUCTION, BIG FOUR RAILROAD.



A. GOVERNMENT WORK. DRIVING PILES FOR DAM 33, OHIO RIVER.

B. CONSTRUCTION OF CONCRETE LOCK FOR DAM 35, OHIO RIVER.



CAR BARN REPAIR WORK. TRUCK REPAIR.

panies, and other branches of industry, according to the localities in which the schools are situated. The results of the New York experiment hitherto have been such as to refute the arguments that the cooperative course can succeed only in a few occupations and in small centers.

POSSIBLE EXTENSION OF COOPERATIVE EDUCATION.

Agricultural education.—Recognition of the opportunities for cooperative education in agriculture is now general, and it is likely that before long the plan will be given a thorough trial in connection with schools and colleges favorably located for such cooperation. The statement of A. C. Monahan, of the United States Bureau of Education, as reported in the Cincinnati Enquirer of March 20, 1915, expresses a conviction which is shared by many educators, regarding the opportunities for cooperative education in the agricultural sections of the United States:

> The Schneider system of combining practical with theoretical studies and giving credit for results achieved in both ways is destined to be adopted generally in technical schools and urban and rural high schools throughout the country. A large number of persons have indicated their hope that a cooperative agricultural educational scheme of this character might be adopted in the Southern States.
>
> Under the Schneider system a student works part of the time in school and part of the time in the shops. As the idea has been worked out in Northampton, Mass., a rural student is given credit for the time passed in doing ordinary farm chores, provided that he uses intelligence in his methods of work and in the observation of results.
>
> There is no particular cultural value in a boy milking cows, for instance, or cultivating corn, after he has done it a few times, but if he will do a certain amount of reading in connection with the work, keep records of yield and cost, and make experiments which require him to think, that is educational.
>
> In the Northampton (Mass.) High-School course of four years the students have four home tasks for which they are given credit. Each task consumes a year. If the student essays to cultivate an acre of ground the first year, he will be given credit for that, if he follows instructions. The next year he may decide to take charge of two, four, or six cows, according to his age. He must do all the work himself and keep detailed records, to secure credit at the school. The system has proved to be very helpful to the school and to the community.

In the agricultural colleges, the winter courses for farmers, now everywhere established, might easily be made the beginnings of a cooperative system. Better still would be the six-months courses, which begin after wheat sowing and end in time for spring plowing. The mere alternation of work and study, of course, means very little; but if the two periods were organized according to a systematic plan for the coordination of theory and practice, there is no reason why a cooperative course in agriculture could not be made a success. If such a plan were adopted, the model farm at the State college would be supplemented, if not displaced, by the various agricultural plants over the State, with their wealth of educative material.

Proposed national university.—Among the many opportunities for the application of the cooperative principle in graduate and professional education, perhaps the most significant are those which have been mentioned in connection with the proposed national university. Dean Herman Schneider, in a statement before the House Committee on Education, January 26, 1914,[1] and President Charles William Dabney, in a statement before the same committee, February 27, 1914,[2] have explained different phases of the cooperative plan which would naturally apply to a national institution of this kind. The former emphasizes especially the selection and training of men for public service, and the latter, the utilization for instructional purposes of the vast scientific equipment of the United States Government at Washington.

The following is quoted from Dean Schneider's statement:

The proposal that the Government establish a National University at Washington presupposes that the Government has a definite educational problem to solve, and that no existing agencies do or can solve it. Juxtaposed statements of the many problems facing the nation which can be met by education and of the facilities offered by the established institutions of higher learning disclose at least one major problem unsolved or insolvable without the organization of a new institution—the training of experts to do the work distinctly peculiar to the Government. Such work, for example, includes service in the diplomatic and consular fields, in the Patent Office, in the Bureau of Engraving and Printing, in the Agricultural Department, in the Industrial Relations Commission, in the Interstate Commerce Commission, and in many other other departments and commissions.

It is evident without argument that the high degree of efficiency required to meet the growing complexity of governmental activities can best be obtained by selecting persons of reasonably demonstrated fitness for the service, training them in the actual work, and supplementing their training with an equal amount of coordinated instruction and research.

The application of the cooperative plan to a National University having as one of its functions the training of Government experts can be considered most succinctly under the three basic principles of the system—selection, practical training, and coordinated instruction.

At the University of Cincinnati the applicant is required to present a high-school scholarship record which presumably indicates his mental ability. He is then required to serve three months of full-time work under observation in the field of engineering he has chosen. If he gives evidence of fitness, he is admitted to the university. The real weeding out of the inapt and the relocation of the able but misplaced go on through five years of combined work in theory and practice.

The National University, however, will be a graduate school, and hence its selective system will be simpler and surer, for during his undergraduate career a young man demonstrates his positive tendencies. Thus, in biology he may show marked ability, and take his majors in this science. He should have a knowledge of the subject sufficient to enable him to enter certain scientific bureaus of the Department of Agriculture, and it has been shown that he should have a strong bent toward biological work of this character. Upon graduation from his undergraduate school, and pre-

[1] Published in the Engineering Record, Apr. 11, 1914.
[2] Published in School and Society, July 10, 1915.

senting proofs of his special ability, he might be admitted to the bureau and to the National University. Since the system would apply to all or nearly all of the Government departments, the National University, together with the department and bureau chiefs, could specify the major studies in which an applicant must be proficient in order to enter any particular department. Thus, upon investigation it might be found that the applicant for training in the Consular Service should present majors in history, political science, economics, and international law; and in the Coast and Geodetic Survey courses in civil engineering, with special work in astronomy. In short, the requirements for admission would be: First, the successful completion of an undergraduate course, containing such major studies as might be required to begin work in a special department; and, second, reasonably demonstrated ability for the work selected.

The organization of the practical work would be effected by conferences between the heads of the cooperating departments and the National University professors. Thus, the question to be met in training men for the Consular Service would be what departmental experience a well-trained consul should have. Analysis and synthesis would lead to a plan of carefully selected progressive experience in appropriate bureaus of several departments—State and Commerce, for example. It is not improbable, too, that further experience in a banking concern doing a diversified foreign business would be found advantageous. The occasional use of privately owned training facilities could be arranged without difficulty. The essential factor in the training part of the scheme is planning the practical work to meet comprehensively the demands of the positions for which the graduate students are being trained.

Successful completion of the cooperative training should insure entrance into the service, at a grade to be determined, just as graduation from West Point guarantees admission into the Army with a certain standing. Indeed, there seems to be no rational reason why training for important posts in the civil service should not be as much a function of the Government as training for like posts in the military service. The present method of selection by examination is admittedly an expediential compromise. Unquestionably, the additional cost of the university to the Nation would be more than met by the increased efficiency of the Nation's servants. Nor need the cost be great; for under the cooperative system the university uses existing facilities, and hence its expense is confined to teachers, classrooms, and special laboratories. In fact, the cooperative system is merely a combination of the old-fashioned thorough apprenticeship and the old-fashioned "college," with the obviously necessary coordination.

The old-fashioned apprenticeship possessed real educational values, but because of specialization it has been gradually disappearing instead of extending to more and higher phases of human activity. Fortunately, we are beginning to realize that our carefully designed mechanisms for production, construction, and distribution are in the truest sense laboratories, whose educational worth it were folly to ignore longer. More significant still, because of the rapidly growing complexity of governmental functions, are the educational opportunities at Washington. Their utilization through cooperation would enhance manyfold the value of the National University.

The specific work outlined in the foregoing is not exclusive; it could not possibly interfere with any other work which might properly be done by the proposed institution.

In his statement Dr. Dabney said:

Another consideration in advocating a National University of this type is the duty of utilizing these vast stores of scientific material in Washington as completely as possible for the advancement of knowledge. It is a well-known fact that the demands of the Government for immediate economic results compel its scientific staff to devote its energies almost exclusively to the study of those problems which have practical ends. The rich materials for the advancement of pure science are thus, in a large measure, necessarily neglected. If in each of the Government scientific bureaus there were a number of students working on their material with reference to the advancement of pure science, the world would certainly get a much larger output of results. The utilization of material by a limited number of students of this character need not interfere at all with its use for economic results. On the other hand, a complete scientific study of the material would undoubtedly greatly promote the efficiency of the departments in reaching the immediate results demanded by the Government. The presence and work of advanced students would undoubtedly greatly improve the work of the Government scientific staff itself.

REQUISITES FOR A SUCCESSFUL COOPERATIVE SYSTEM.

Notwithstanding the many possible applications of the cooperative system, only a few of which have been indicated, it would be a mistake to assume that this type of instruction can easily be put into successful operation in any given combination of circumstances. It will be recalled that the cooperative course was first suggested by the existence, side by side, of an institution for teaching young men and a great industrial plant in which as graduates these same young men would put their theory into practice. Under the cooperative plan it was proposed merely to take advantage of what may be called the "laboratory of industrial environment" in the training of students whose book learning found practical illustration in that environment. Since one community varies widely from another in the nature and extent of its industrial interests, there must be a corresponding variation in the details of a cooperative course designed to fit a particular community. Thus, the cooperative course in engineering which has been developed at the University of Cincinnati could not be successfully adapted in its entirety by the University of Akron (Akron, Ohio), the University of Pittsburgh (Pittsburgh, Pa.), or the Georgia Institute of Technology (Atlanta, Ga.). Each institution has its own peculiar set of conditions, industrial and educational, and whoever plans a cooperative course must take account of these conditions.

Nor does the adaptation end with designing and establishing the course. Unlike the regular course, which can be administered within a comfortably definite routine, the cooperative system is a perpetual challenge to the vigilance and ingenuity of the executive force. There are, to be sure, no insuperable administrative difficulties, but there are frequent surprises and small adjustments that call for watchful supervision. Still more depends, however, upon the spirit of the teaching staff and of the student body. Although teamwork and a friendly attitude of "give and take" are important in any union of effort, they are vital to the cooperative course; they are, in fact, the essence of cooperation.

APPENDIX A.

TYPICAL INSTRUCTION SHEETS AND OUTLINES.

OBSERVATION OUTLINES FOR COOPERATIVE STUDENTS.

The work syllabi, or observation outlines, extracts from which are given on the following pages, are intended to serve a twofold purpose: First, to make the student a more intelligent, and consequently a more efficient, workman; and second, to emphasize the instructional value of the practical work, by showing the relation between the student's practice and his theory. The three types of work which have been chosen for illustration are as follows: Electric car trucks, foundry metallurgy, and engine lathe.

ELECTRIC CAR TRUCKS.

Many cooperative students, especially in electrical engineering, begin their practical work in the shops and barns of the Cincinnati Traction Co. Some idea of the variety of experience afforded by this work may be gained from the excerpts given below.

No. 15. ELECTRIC CAR TRUCKS—REPAIR AND MAINTENANCE.

Name.............................. Date..................

Student apprentices employed by the local traction company in their car barns and repair shops are generally engaged in the repair of the rolling stock. In detail, the work consists of—

(a) The repair and adjustment of trucks, brakes, motors, controllers, heaters, lights, switches, and electrical protective devices;

(b) The wiring of cars, connecting motors, controllers, heaters, lights, switches, and electrical protective devices;

(c) The inspection of parts of cars to ascertain whether repairs are needed; and

(d) Machine work in which new parts are manufactured or built to replace those worn out in service.

The questions on the following pages which deal with the maintenance and repair of trucks and related parts are grouped for convenience as follows: Motor suspension; gears and pinions; wheels and axles; bearings; lubrication.

While the mechanical work of repairing trucks is of a rough type, compared with many machine-tool operations, the experience, nevertheless, is of great value to the engineering apprentice, on account of the numerous applications of technical theory encountered. Attention will be called to many of these applications by the coordinating questions on the following pages. Questions relating purely to practical work are numbered. The questions which show the theoretical connections are lettered and grouped with the corresponding practical question. The branches of science involved are shown in parentheses, together with the year of the university course in which these subjects are studied.

REFERENCES ON ELECTRIC CAR REPAIR AND MAINTENANCE.

Machine Reference Series No. 34, Care and Repair of Dynamos and Motors.
Machine Reference Series No. 74, Electric Magnetism.
Machine Reference Series No. 75, Motors, Generators, and Electric Railways.
Electric Road Maintenance—*Jackson*.
American Electric Railway Practice—*Herrick and Boynton*.
Modern Electric Railway Motors—*Hanchepp*.
Elements of Electric Traction—*Gant*.
Electric Railways—*Ashe*.
Electric Railway Handbook—*Herrick*.
The Motorman and His Duties—*Gould*.

CHARACTERISTICS OF DIFFERENT TYPES OF TRUCKS.

1. What are the essential differences between the trucks of single and double-truck cars? Which type of car can take the shorter curve, and why? Which can take a given curve at the higher speed, and why? Which type is in greater use by the local traction company? Are there any lines on which either type can not be used? If so, state the reasons.

A. What determines the minimum radius of the curve around which any *truck* can pass? (Coor. -1, 2.)

B. What determines the minimum radius of the curve around which any *car* can pass? (Coor. -1, 2.)

C. How would you measure the radius of a track curve on a city street? (Math. -1.)

D. In what units are the radius and the length of a curve expressed? (R. R. Surveying Theory -3 E. E.)

2. Define clearly and state the functions of each of the following parts of trucks, and give the materials of which each part is made: Frame, bolster, transom, center-plate, king-pin, equalizer springs, equalizer bar, pedestals, journal boxes. side-bearing plates. journal brasses. motor axle, sleeves.

3. What is the object of "hanging" the spring plank from the transom, and in what way is this done?

4. Show how the different locations of brake shoes on a truck influence its design. (For detailed questions on brakes, consult special sheets.)

5. Explain the functions of the side bearings of a car. What is the difference in their action when the car is filled and when it is empty? How much clearance is usually given in these bearings? What is the result of too much clearance? Of too little? To what extent are these bearings cushioned on wooden blocks? State your opinion of this practice.

6. Be able to show by a sketch the construction of a full elliptical spring. How are the various leaves held together, and how are the ends of the outer leaves tied? How many leaves are used in the springs of trucks under your observation, and about what is their thickness?

A. What is the moment of a force? What is a bending moment? (Mechanics -3.)

B. In a leaf spring, why are more leaves necessary under the point of application of the load than near the ends? (Elem. of Eng. -1; Mech. -3.)

7. Describe the maximum traction truck and explain the significance of its name. What provision puts the greater part of the weight on the large wheels? Why is this desirable? State the object of using different sized wheels on the same truck. How does the danger of derailment in a truck of this type compare with that of trucks, symmetrically loaded?

A. What class of lever have we, if we consider the center of the small wheel a fulcrum, a point opposite the king-pin as the point of application of power, and the center of the large wheel as the load? (Elem. of Eng. -1; Phys. -2; Mech. -3.)

B. If we consider the side frame of the maximum traction truck as a beam, with the load applied at the point opposite the king-pin, show how to calculate the reaction at each axle journal. (Elem. of Eng. -1; Mech. -3.)

38. How is the power transmitted from the gear to its axle in the case of (*a*) pressed fits; (*b*) of split gears? In which case are keys necessary, and why are they not necessary in both cases? What kinds and sizes of keys are used for each type of gear used by your company?

A. Is the width of face of a gear usually designed merely to resist all stresses with the correct factor of safety, or is it made wider than necessary in order to decrease the unit pressure and the resulting wear? (Mach. Des. -3.)

39. Explain by a sketch how the armature pinions are fastened to their shafts. Are their seats tapered or straight? Can they be removed? Of what grade of material are such keys made? What kinds and sizes of keys are used?

A. Why is a pinion often made wider than its gear? (Mach. Des. -3.)

B. Which wears the more rapidly, the pinion or the gear? Why? (Mach. Des. -3.)

FOUNDRY METALLURGY.

The following questions are part of a syllabus on foundry work. In addition to metallurgy, the sheets on foundry practice include hand and machine molding operations, core making, and foundry management.

No. 12. Iron Foundry (Metallurgical Sheet).

Get the following data and measurements in regard to the cupola used at your foundry. These data will be useful in studying comparative cupola performance in connection with the subject of metallurgy.

1. Diameter of cupola (in inches).
2. Height of tuyeres from sand bottom (in inches).
3. Height of charging door above tuyeres (in inches).
4. Height of charging door above tuyeres divided by diameter (in inches).
5. Number and arrangement of tuyeres.
6. Size of tuyeres (in inches, vertical and horizontal).
7. Area of tuyeres (in square inches).
8. Cupola area is how many times tuyere area?
9. Diameter of blast pipe (in inches).
10. Blast pressure 20 minutes after start (in ounces).
11. Class of work made.
12. Relined, how often.
13. Weight of bed charge of fuel (in pounds).
14. Weight of iron in bed charges (in pounds).
15. Weight of fuel in charges subsequent to the bed charge.
16. Weight of iron in charges subsequent to the bed charge.
17. Total weight of fuel, one run (in pounds).
18. Total weight of iron, same run (in pounds).
19. How many pounds of iron are melted by 1 pound of fuel?
20. Kind of fuel used.
21. Fuel measured by weight or by volume?
22. Height of fuel bed above tuyeres (in inches).
23. Thickness of fuel charges after the bed charge (in inches).
24. Thickness of iron charges after the bed charge (in inches).
25. Time before iron appears after blast is on (in minutes).

26. Time to melt each iron charge after the bed charge (in minutes).
27. Total iron melted per minute (in pounds).
28. Total iron melted per minute, per square foot cupola area.

Find from your foundry the answers to as many as possible of the following questions:

1. *Mixtures.*—How many different iron mixtures are used on the work at your foundry? What are their distinctive chemical differences? For what class of castings is each used, and why? How many and what mixtures are poured in the same run? How are the different mixtures prevented from mixing in the cupola? In what order are the mixtures melted? Why?

2. *Pig, scrap, and coke.*—Give names and as many as possible of the characteristic chemical differences of the various grades of pig iron and scrap used. What are the prevailing market prices of these grades? What kind of coke is used and what is its cost?

3. *Zones.*—What are the exact locations and thicknesses of the crucible, tuyere, and melting and stack zones of your cupola? What takes place in each during melting?

4. *Melting practice.*—What is the range of sizes of commercial cupolas? Does the diameter of the cupola affect the weight of the various charges of iron and fuel? Why? If it takes longer than usual for the iron to run, after the blast is turned on, what does this fact indicate? What is the effect of too thick layers of coke? Why? What is the effect of too thick layers of iron? How is this noticed? Is it possible to have alternate layers of iron and fuel too thin? How is very hot iron produced? What percentage of pig iron charged is lost in melting and pouring? In what ways does this loss occur? Why?

5. *Chemical changes.*—Do iron castings ordinarily contain more, or less, sulphur than pig iron? Why? How much? Why is the first and last iron drawn relatively higher in sulphur than the rest? How can the amount of sulphur in the last iron drawn be reduced? Why? Do castings contain more, or less, silicon than the original pig? Why? How much? What materials are charged to form a slag? Give both their chemical formula and their physical form. Is any fluorspar used? Why? What are the advantages and disadvantages of a high state of fluidity in the slag? What becomes of the dirt on the pig iron? What becomes of the ash of the coke? What gases come from the top of the cupola? What is a "cutting flame"? What causes it, and how is it recognized?

ENGINE LATHE.

The outline on the engine lathe deals with three principal phases of the student's experience: (1) The operation of the machine, (2) the design of the machine, and (3) the management of the department in which the machine is used.

No. 3. Engine Lathe.

Name.............................. Date....................

In running any machine tool, the important points are: (*a*) The fastening of the work, (*b*) the choosing and setting of the correct cutting tools, (*c*) the selection of the proper feeds and speeds and the taking of the cut.

Questions Nos. 1–75, inclusive, on the following sheets, will guide you in a study of your work. For convenience they are arranged under the following headings:

(A) Lathe tools—kinds, uses.
(B) Speeds and feeds.
(C) Fastening and supporting of the work.
(D) Typical lathe operations.
(E) Taper turning and boring.
(F) Thread cutting.

Answers to these questions will be found in your experience or in the references given below.

REFERENCES.

Catalogue of the firm making your machine.
Operation of Lathe, Part 1, Machine Reference Series.
Operation of Lathe, Part 2, Machine Reference Series.
Principles of Machine Shop Work—*Smith*.
Lathe Design—*Nicolson*.
Modern Machine Tools—*Benjamin*.
The Art of Cutting Metals—*Taylor*.

1. What is an engine lathe? Write the names of 20 of the principal parts of your lathe.

2. When is a lathe tool right-handed and when is it left-handed? Sketch top views of the following: Round-nose rougher, wide-nose finisher, side tool, bent left-side tool, brass tool, parting tool, vee-thread tool, and boring tool.

LATHE TOOLS, SHAPES, SETTINGS, AND GRINDING.

3. Define and show by sketch: Clearance, back slope, and side slope. What is the object of each of these?

4. Why has a round-nose roughing tool a curved cutting edge?

5. Why is there danger of spoiling the work by setting a round-nose tool with its nose pointing in the direction of the feed? How is this danger eliminated—(*a*) when turning, (*b*) when boring?

6. What is the danger of spoiling the work when the point of the tool is set above the axis of the work and projects too far out from the tool post?

7. Show by a sketch the effect on the clearance and on the effective top slope of having the tool set—(*a*) above center, (*b*) below center. For ordinary turning, what is the correct height of the tool? What is the effect of too small a cutting angle when cutting hard material? Why should the top slope be zero or slightly negative for brass and other soft materials?

8. What is meant by burning a tool when grinding? What precaution can be taken to avoid this?

9. What is the special advantage of using tool holders? Sketch two different forms.

10. What are forming tools? How are lathe-forming tools sharpened without changing their shape? On what work are they used?

SPEEDS AND FEEDS.

11. What is meant by the cutting speed on a lathe? How is the correct cutting speed determined?

12. What is the effect of too high a cutting speed? In general, what do you consider to be the most economical cutting speed for a given job?

13. How does the cutting speed vary with different materials worked on? With depth of cut and feed? Why is the maximum speed for cast iron lower than that for steel?

14. A piece of lathe work 12 inches in diameter is turning at 18 r. p. m. What is the cutting speed?

15. A certain material permits a cutting speed of 90 feet per minute. Its diameter is 6 inches. What would be its r. p. m.?

FASTENING OF WORK.

17. Name four methods of fastening work in a lathe.

18. By means of sketches, show three ways of locating the center of a round shaft by hand, preparatory to drilling the center holes.

19. What are two advantages of centering by means of a machine? By means of a sketch show why bent work should be straightened before centering.

20. What is the angle of lathe centers? Show by a sketch the result in each of the following cases—(a) when the center hole of the work has a smaller angle than the lathe center; (b) when it has a larger hole than the lathe center.

23. Which end of the mandrel receives the dog? Show by sketch the effect of using too short a dog.

24. Describe two types of expanding mandrels. Use sketches.

25. What is a roller mandrel? Sketch a section through one and state its particular advantage over a plain mandrel.

79. Why will a machine with a single-pulley drive often deliver more power to a tool than a cone-driven machine? Calculate the maximum possible cut speed on work of minimum possible diameter. Calculate the minimum possible speed on work of maximum possible diameter. Why are these values significant?

80. How is the feeding mechanism connected to the driving mechanism? By what mechanism is it possible to secure variable feeds? How is the amount of feed designated? Make a list of all feeds.

81. Has this lathe a feed rod separate from the lead screw? Why? If not, is the lead screw splined? Why? What is the pitch of the lead screw? Of the cross-feed screw? Can the lead screw and the feed rod be engaged at the same time? Is there a chasing dial? If so, into how many divisions is it marked? What are the high and low limits of the threads possible to cut?

82. What angles are used on the carriage ways? Have these been chilled? Are the centers set half way between the Vee ways or not? If not, where are they, and why?

83. How is the carriage gibbed to the bed? How is the compound rest gibbed to the carriage? How is the apron secured to the carriage?

84. Can the longitudinal and cross feeds be engaged at one time? If so, what angle will this tend to cut? Is the tool rest plain, swivel, or compound? What is the difference in the construction and use of each of these? What is the maximum possible size of tools? Is there any taper attachment?

85. Give the material of each of the following, including any heat treatments given to the gears: Bed, carriage, tailstock, spindle, tailstock spindle, apron, driving pulley, face plate, hand-feed handles, spindle bearings, gibs, dead center, live center, back gears, driving gears, and gears in apron.

86. In order that the lathe may do accurate work, what alignments relative to each other are required of the spindle, carriage ways, centers, and cross slide?

87. Assume the machine to be pulling a heavy cut. Without calculations, tell roughly the directions of the forces which resist the pressures of the cut longitudinally, crosswise, and torsionally; and tell in what members these forces act.

88. Can you ascertain in what positions the castings for the bed, headstock, tailstock, apron, and carriage were poured in the foundry? Can you tell which portions of each of these were in the cope, and which were in the drag? What parts required the use of cheeks?

89. What points were incorporated in the design of the above castings to secure the necessary rigidity? What points were incorporated to insure freedom from certain metallurgical faults in the castings?

104. What kinds of tool steel are used for the forged tools? By whom are such tools made? By whom dressed? What makes of toolholders are used? To what extent and on what classes of work? What brands of taps and reamers are used? What types of reamers are most common? By whom are the form tools and special cutters designed? By whom made? By whom resharpened or ground? What brands of the above tools would you recommend, and why?

105. What types of chucks and face plates are in most general use? Are chucks and face plates ever used on other machines than those for which they were built?

What makes of chucks can you recommend? What kinds of mandrels are used? Are they made in your own tool room? What is the practice in regard to the amount of taper used on the different types of mandrels?

106. Give a list of all special attachments and fixtures used on lathe work. What is the special use of each? What fixtures have you needed in your work which were not to be had?

107. Give any standard allowances used in your department in making running, drive, press, or shrink fits. Give a concrete example of one of each of these fits made in your department. Is the variation from standard put on the male or the female part?

108. What kind of crane or hoist service has the department? Describe, and give all possible data. Note also whether the department is provided with such facilities as arbor presses and centering machines.

109. Describe all tickets and tags which accompany the work through the department. Bring in a sample or sketch of each, explaining its use. How long does work remain in the department on an average? From what departments does it come, and to what departments does it go when finished? How much work is turned preparatory to finishing in a grinder? How close to size is such work turned? What are the average sizes of lots for different types of work? Can you ascertain how the foreman keeps his records of work completed, work under way, and work soon to come?

110. What lubricating or cooling compounds are used? How are these mixed, and how applied? How are they stored before mixing? What provisions are there for cleaning machines? Of floors? By whom cleaned?

111. Sketch freehand—(1) Lay-out of department, and (2) vertical section through shaft hanger.

INSPECTION TRIP REPORTS.

COORDINATION 1, 3, AND 5, AND ENGLISH 41.

Although the inspection trips outlined below are made a part of the work in coordination, the reports are counted as themes by the English department and are thus criticized both for subject matter and for expression. A similar plan is followed in the case of inspection-trip and laboratory reports written by upper-class men.

INSPECTION TRIPS AND ELEMENTS OF SHOP PRACTICE.[1]

(*Cf.* Instructions for Eng. 41.)

Dates. Sec. 1.	Sec. 2.	
Sept. 21	Oct. 6	Preliminary discussion.
Sept. 24	Oct. 8	Names and uses of small tools.
Sept. 29	Oct. 13	Measuring tools and gauges.
Oct. 1	Oct. 15	Micrometers and verniers.
Oct. 20	Nov. 3	Foundry tools and appliances.
Oct. 22	Nov. 5	Description of Cincinnati waterworks.
Oct. 23	Nov. 6	Inspection trip No. 1.—California waterworks.
Oct. 27	Nov. 10	Discussion of above trip.
Oct. 29	Nov. 12	Foundry materials—types of molds.
Nov. 17	Dec. 1	General foundry methods.
Nov. 18	Dec. 3	Description of foundry to be visited.

[1] This part of the work is not listed separately in the catalogue, but is given in connection with coordination 1, 3, and 5.

Nov. 20	Dec. 4	Inspection trip No. 2.—Foundry. Laidlaw Dunn Gordon Co.
Nov. 24	Dec. 8	Discussion of foundry trip.
Nov. 26	Dec. 10	Review and quiz on work to date.
Dec. 15 Dec. 17	Christmas vacation.	Materials of mechanical construction.
Christmas vacation.	Jan. 5 Jan. 7	Names and uses of machine tools.
Jan. 12	Jan. 26	Methods of removing metal by machine tools.
Jan. 14	Jan. 28	Description of machine shop to be visited.
Jan. 15	Jan. 29	Inspection trip No. 3.—Machine shop. The Cincinnati Milling Machine Co.
Jan. 19	Feb. 2	Discussion of machine shop trip.
Jan. 21	Feb. 4	Reasons for different types of each of the standard machine tools.
Feb. 9	Feb. 23	Some types and uses of electrical machinery.
Feb. 11	Feb. 25	Description of power plant to be visited.
Feb. 12	Feb. 26	Inspection trip No. 4.—Power plant. The Oakley Colony Power Plant.
Feb. 16	Mar. 2	Discussion of power plant trip.
Feb. 18	Mar. 4	Arrangements of A. C. and D. C. circuits.
Mar. 9	Mar. 23	Materials of electrical construction.
Mar. 11	Mar. 25	Description of electrical plant to be visited.
Mar. 12	Mar. 26	Inspection trip No. 5.—Electrical manufacturing plant. Bullock Electrical Mfg. Co.
Mar. 17	Mar. 30	Discussion of electrical trip.
Mar. 18	Apr. 1	Precautions necessary around electrical work.
Apr. 6	Apr. 20	Hardening and tempering.
Apr. 8	Apr. 22	Casehardening and annealing.
Apr. 9	Apr. 23	Inspection trip No. 6.—Chemical plant. Jarecki Chemical Co.

English 41.[1]

(One hour a week.—Given in connection with Coordination 1, 3, and 5, and Chemistry. Prerequisite—Entrance requirements in English).

Object.	Method.	Matter.	Mechanism (administration).
To develop the ability to organize material into a clear and comprehensive report. To review and apply the principles of composition. To discover weaknesses in the writing ability of individual students. To correct faults in expression, particularly in such matters as paragraphing, sentence structure, spelling, and punctuation. To increase the student's vocabulary and to make him more accurate in the use of words.	Lectures on the principles of composition as applied to the writing of reports. Written instructions to guide the student in writing reports. Examples of good and bad form in inspection—trip reports. Criticism of reports by the instructor and the class. Revision and rewriting of reports by the students. Conferences with individual students. Additional study and practice required of those students who show poor preparation in English. Technical terms supplied and explained by the department of coordination. Credit given for form as well as for content in all written work, regardless of the branch of study involved.	The whole composition and the paragraph: Subject, purpose, material, organization—unity, coherence, and emphasis. The sentence. Vocabulary: Technical terms; general and specific words. Spelling; punctuation; abbreviation; use of figures; style in engineering reports; and standardization of mechanical details, such as covers, margins, paragraph indentations, position of titles and headings, writing of formulas and chemical equations, placing of sketches, and indorsement of manuscripts.	All reports graded for English as well as for subject matter. On a blackboard record reports are checked when received, and grades in English are recorded before the reports are passed on to the department of coordination. Card catalogue[2] of individual students contains record of the following details for each report: Organization, sentence structure, vocabulary, spelling, punctuation, manuscript, and grade in English. Sketch required with each report. Manuscripts written on uniform paper and bound in standard manila covers. Students meet regularly in groups of 6 to 8 for the criticism of reports.

[1] From "Cooperative Course in English for Engineering Students," by C. W. Park, Bull., Soc. for Promotion of Engineering Educ., Vol. V., No. 9, May, 1915.
[2] The following is a typical card used for this purpose:

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Name of student..................... Course........... year...........

Grade.	Organization.	Sentences.	Vocabulary.	Spelling.	Punctuation.	Remarks.
Ex. 1						
Ex. 2						
Ex. 3						
Ex. 4						
Ex. 5						
Ex. 6						
Ex. 7						

It will be observed that the operation of the course just outlined is made as nearly automatic as possible. Smoothness of administration is perhaps the chief essential to success in cooperative courses, and it is for this reason that written exercises regularly required in other departments were made the basis of the course. It will also be noted that, in the division called "Matter," a portion of the theory usually taught in separate English composition courses is included. By distributing the theory in this way through the various cooperative courses, considerable time is saved for literature and literary composition in the regular course in English.

APPENDIX B.

A BIBLIOGRAPHY OF THE COOPERATIVE SYSTEM.

[A complete record of the published matter dealing with the cooperative system would necessarily include many newspaper articles, for from its very beginning the cooperative plan has received a great deal of attention from the general public, as well as from educators and technical men. The newspaper material given here is restricted mainly to a few articles which mark important dates and events in the development of cooperative education, or which report papers and discussions not elsewhere published. It is to be regretted that the original paper proposing a cooperative scheme for technical education, which was submitted by Dean Schneider in 1902, has not been printed. The main propositions set forth in this paper are embodied in the section on the cooperative idea, page 7 of this bulletin.]

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Another phase of cooperative engineering. (Editorial.) American machinist, June 11, 1908.

Ayer, Fred E. A cooperative course in civil engineering. Concrete engineering. June, 1909.

Board of directors adopts cooperative scheme. (Editorial.) Cincinnati commercial tribune, April 17, 1906.

Cooperative industrial training. Chattanooga times, January 16, 1910.

Urges the adoption of the cooperative system in the University of Chattanooga.

Dabney, Charles William. The university and the city in cooperation. Outlook, July 25, 1908.

Du Brul, E. F. The Cincinnati plan of cooperative technical education. Cincinnati commercial tribune, May 25, 1908.

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See also pt. 2. p. 132–134.

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