# ACHIEVING AN OPTIMAL BALANCE BETWEEN GENERAL AND SPECIALIZED TRAINING IN HIGHER EDUCATION

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The question of how to achieve an optimal balance between general education and vocational training in higher education is an old one. Even if we assume that a method for the perfect achievement of such a balance may never be found, the fact remains that the quality of vocational training itself is negatively or positively affected according to another balance: that between general and specialized (vocational) training.

As separate factors, general and specialized training play different roles in bringing about such a balance. Many persons believe that imbalances between general and specialized training can be corrected through further training. Although it may indeed give some good results, it cannot be regarded as the best solution.

The root of the problem is that we tend to view balance as a pair of scales. On one side we place general subject matter and on the other, specialized disciplines. Then we wonder why the scales tip toward the side of general subject matter (Figure 1).

We try, of course, to maintain equilibrium either by adding something to the side which is too light or by taking something away from the side which is too heavy. Unfortunately this process is very awkward, primarily because we do not place the two factors on the scales simultaneously. In fact, the usual practice in the training of engineers is to introduce the student, during the first 2 to 3 years of his course-programme, to general course material which is theoretical and abstract. Only near the end of his training, during the 4th or 5th years, will he be exposed to material which is concrete and practical, consisting, more or less, of specialized subject material (deductive structure of curriculum).

Such an order of presentation makes it *a priori* impossible to establish a proper balance. Our belief is that a bold step should be taken: the modification of the traditional deductive educational process.

The structure of the proposed new curriculum is *conductive*, meaning that *the teaching of the general and the specialized, the theoretical and the practical, the abstract and the concrete should be carried on simultaneously throughout the full period of education, from the first year to the last.*

In the case of a conductive curriculum, balance can be given almost automatically, because the general and the special is placed simultaneously in an optimal ratio on both sides of the scales (Figure 2).

A further advantage of a conductive curriculum is that it gives rise to training processes which are much more efficient than those of deductive curricula.

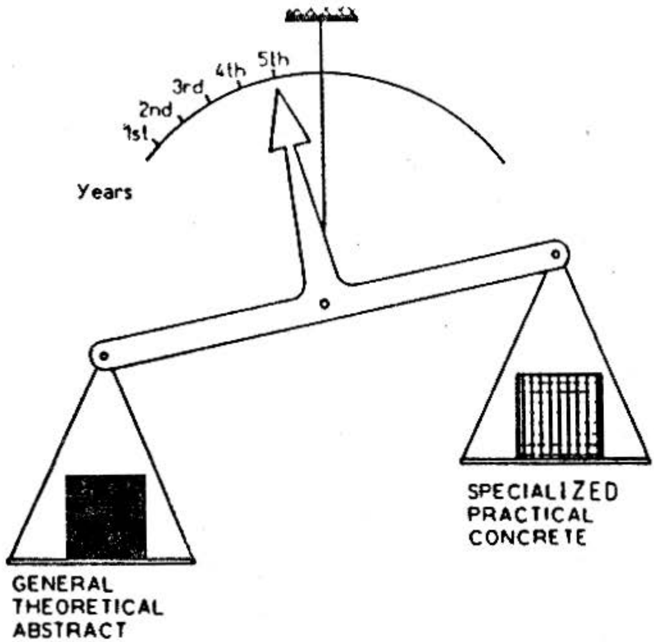


Figure 1

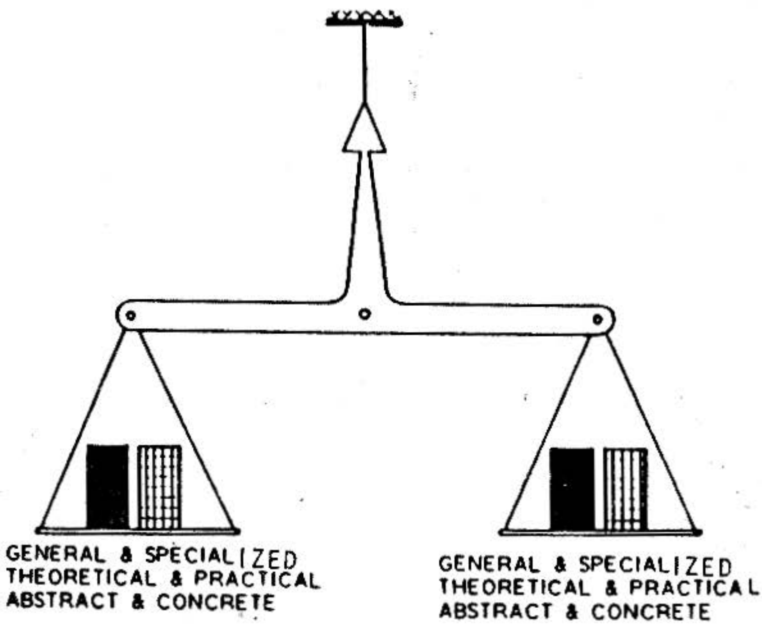


Figure 2

The educational process is extremely complex. To illustrate our argument, we have portrayed our conception of the educational process with the aid of a simplified algorithm (Figure 3), one which we hope will convince the reader of the need for conductive curricula.

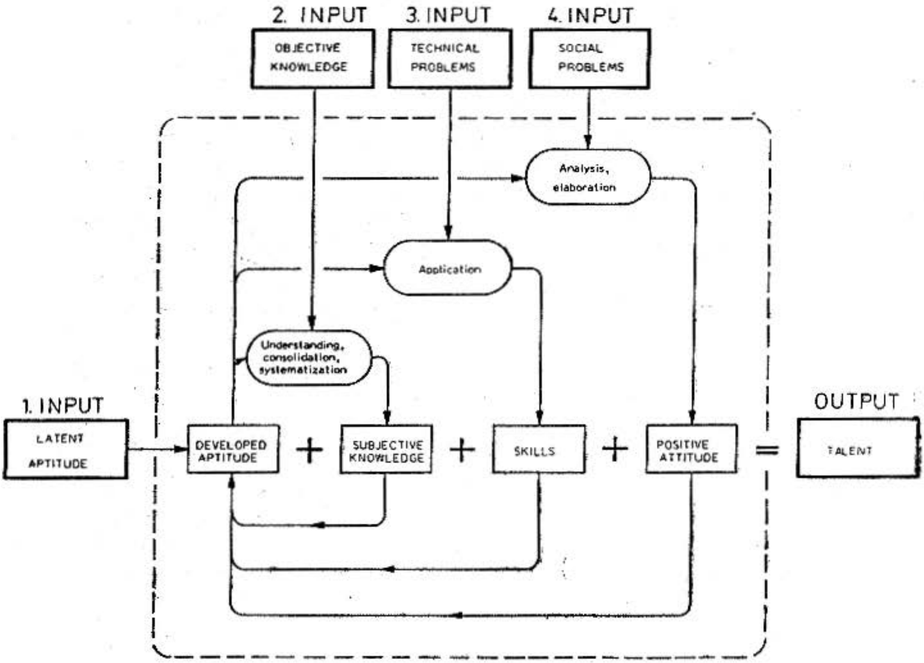


Figure 3

For the sake of simplicity, we have considered only four inputs and one output.

The first input is the *aptitude* of the student. Initially, it is mostly latent and undeveloped. (By *aptitude* we understand the sum total of the student's motivation plus his intellectual and physical/manual endowments).

The second input is *objective knowledge*, which consists of facts (data, phenomena, etc.) and generalizations (laws, theses, theorems, etc.). This knowledge is objective because it exists independently of the student. This knowledge, consisting of facts and of generalizations, may be general or specific, abstract or concrete, theoretical or practical, and so on. The subject matter of instruction, the course material, may consist of only a fraction of the available knowledge on a given subject.

The third input is a selected number of *technical problems*, and the fourth, a selected number of *social problems*.

The educational process consists of three large, interrelated cycles labelled respectively *understanding*, *consolidation*, *systematization*, *application*, and *analysis elaboration*.

Common to all three cycles is the personality of the student represented, in our case, by *developed aptitude*. Since the three cycles (also) contribute to the development of the student's aptitude, the volume of developed aptitude increases steadily during training.

In the first cycle, objective knowledge is added to aptitude. With the same knowledge, the cycle repeats itself several times (many times in fact) with the result that the student develops *subjective* knowledge — i.e., knowledge which is understood, consolidated, and systematized by himself. At this point, the knowledge which the student has gained is of the type found in an encyclopaedia. The specifics of it depend on his field of study, its amount being commensurated with his learning capacity.

In the second cycle, aptitude plus subjective knowledge encounter technical problems. Here, the application of subjective knowledge results in the development of the student's intellectual and physical/manual skills, including the recognition, the definition, and the solution of technical problems. Here we could give a long list of the skills that an engineer might need, but we must stress the fact that a student can develop only those skills for which he has an aptitude. And indeed the aptitudes of given students show great variations.

In the third cycle, aptitude plus subjective knowledge plus engineering skills come up against social problems. In the course of the analysis and the elaboration of these problems, the student develops the *positive attitudes* which enable him to deploy his knowledge and his skills for the benefit of society.

The sole output in this algorithm of the educational process is *talent*, which consists of aptitude, plus knowledge, plus skills, plus positive attitudes, all of which must be highly developed. It is a matter of common knowledge that the development of skills and of attitudes is a *much more time-consuming* process then the development of knowledge: nevertheless, many engineering schools neglect the former or are overly late in dealing with them. The truth is that a deductive curriculum does not permit engineering problems (both technical and social) to flow freely from the beginning into the circulation process of training. Therefore, the circulation that occurs in the initial years does so mostly during the first cycle. Only knowledge increases.

We must caution the reader that even the increase in subjective knowledge is *not truly efficient* in the case of a deductive curriculum because objective knowledge alone is not linked to the practical applications which, in turn, would further all three of the partial processes making up the educational process as a whole: understanding, consolidation, and systematization.

Some say that even in the case of a deductive curriculum possibilities exist for the application of knowledge, a claim which is supported by exemples. Although there is truth to this claim, the connection between knowledge and examples, given the circumstances, is *simplex*. The student only experiences a single aspect of a given problem, not its complex nature. A student who happens to be studying mechanics, for example, will believe that he is able to solve *all* technical problems if he is adept at mechanics. A conductive curriculum, on the other hand, will lead him to *start from the problem* itself in some, although not in all, of the cases. He will thus realize that all technical problems are *complex* in nature and that he will need to have a simultaneous knowledge of *many disciplines* in order to be able to solve them. Moreover, this realization will *stimulate* the student to make further efforts so as to deepen his general, theoretical knowledge.

All things considered, a conductive curriculum also enables the student to attain the different elements of knowledge alternatively, by deductive and by inductive means, each in the way that best suits the given topic.

Generally speaking, the fund of objective knowledge possessed by mankind has been increasing for thousands of years, mostly by inductive means: experience followed by theory. The process whereby we try to produce subjective knowledge in the student from a fractional part of objective knowledge is in fact a *reconstruction* of knowledge. The process would be inefficient if only inductive methods were used — *but the other extreme is no better.* To increase knowledge purely by deductive methods is only feasible in the training of elites. The mass education of today requires the *alternation of deductive and of inductive steps*, a process which is made possible by giving a conductive structure to curricula.

Figure 4 illustrates the five main variations in the kinds of demonstrations (deduction or induction) which can be used in the teaching process depending on the character of the curriculum (deductive, conductive, inductive). As can be seen in the portrayals of an extremely deductive curriculum, on the one hand, and of an extremely inductive one, on the other, only approaches which are deductive in the first case and inductive in the second, can be applied. The conductive curriculum, however, permits the use of both deductions and inductions in an optimal ratio.

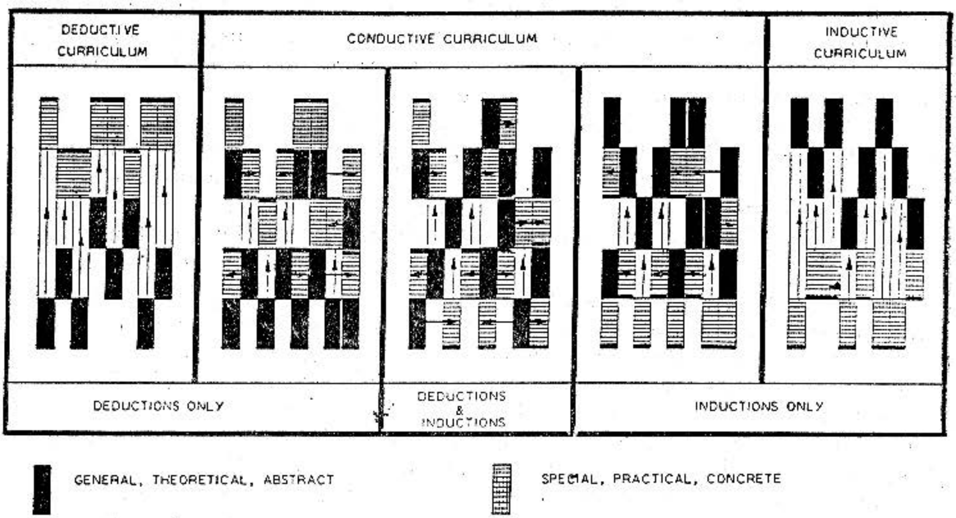


Figure 4

A rough approach to the design of a conductive curriculum would be the simple rearrangement of subjects as they are taught today. Thus a few general theoretical subjects could be shifted to the 3rd, 4th, or 5th years, and certain "specialized" and "practical" subjects could be advanced to the 1st or the 2nd years. Obviously, the contents of these subjects as well as the methods of instruction would need to be modified to some extent.

Such a curriculum has been in effect for about 10 years in the Vehicle Engineering Department of the Budapest University of Technology (Table 1). Although conductive quality is only roughly present, the order in which the courses are taught induces a certain kind of integration into the minds of the students. Were a wholly new curriculum to be devised, however, some of the subjects would need to be replaced by entirely new ones which would be based on the integration of subject matter.

Coming back to the question of balance, we must refer to the process of specialization which seems to begin much too early in the cases of conductive curricula. We wish to make clear that the specialization required for a *given* degree of a *given* nature should be included in a *given* curriculum as early as the beginning of instruction.

In today's era of mass education, it is inconceivable that a student, on registration for an academic course, would not know if he wanted to be an engineer, or a physician, or a lawyer, or a sculptor. This decision, however, is sometimes difficult to make, for it requires that the student have a thorough knowledge of his aptitudes, something which he does not often have at the age of 18.

An additional problem is that a student who wants to be an engineer must decide quite early as to the particular field for which he wishes to prepare: mechanical, civil, electrical, chemical, etc. Here too aptitude plays a role, but a much smaller one than in the choice of profession, for the relationship between aptitude and the chosen field is considerably weaker than is commonly thought. Sometimes it hardly matters whether a certain aptitude is exploited in mechanical engineering or in civil engineering, etc. Frequently the question is less one of aptitude than of mood or of other motivations which may play an important role in the decision.

But the process of specialization is far from over when a student opts for a special field. The student who has made up his mind that he wants to be, say, a mechanical engineer has to make at least two more decisions:

First, what does he want to do as a mechanical engineer? Does he want to be engaged in design, manufacture, organization, research, teaching, trade, etc.? In other words, what sort of *activity* does he want to carry on?

Secondly, what does he want to design, manufacture, etc.? Is he interested in automobiles, excavators, sewing machines, turbines, welding machines, etc.? In other words, what will be the *object* of his activity?

These two decisions do not carry equal weight. His choice of activity is much more important than his choice of object. Different skills are necessary for different activities. The development of skills depends on aptitude. In opting for an activity, the student should take his aptitude into account; he need not do so when choosing an object. The choice of an activity is final or, at least, lasting. In contrast, the choice of an object may be temporary; moreover, one's objects may change several times during one's career. The wrong choice of activity is hard to correct; whereas the wrong choice of object does not entail adverse consequences. The skills one needs for particular activities can be used in connection with many different kinds of objects.

It follows that in the educational process, specialization according to object (if it is needed at all) may occur sooner than specialization according to activity. The reason that this understanding is important for the student is that in numerous cases (although not always so), for methodological reasons,

*Table 1*

**BUDAPEST UNIVERSITY OF TECHNOLOGY**
**Faculty of Transportation Engineering**

| Term | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Philosophy | 1+1 | 1+1 | — | — | — | — | 1+1 | | | |
| Political Economics | | | 1+1 | 1+1 | 1+1 | — | — | 1+1 | | |
| Scientific Socialism | | | | | | 2+2 | — | — | 1+1 | |
| History of Hungary | | | | | | 1+1 | | | | |
| Foreign Language | 0+3 | 0+3 | 0+3 | 0+3 | 0+3 | 0+3 | 0+3 | 0+3 | | |
| Gymnastics | 0+2 | 0+2 | 0+2 | 0+2 | | | | | | |
| Driving of Automobile | | 0+2 | | | | | | | | |
| Human Electives | | | | | 0+2 | 0+2 | | | | |
| Military Course | | | | | 0+2 | — | — | 0+2 | | |
| Law | | | | | | | | | 0+2 | |
| Industrial Safety | | | | | | | | | 2+0 | |
| Computer Programming | 1+3 | | | | | | | | | |
| Engineering Physics | 4+3 | | | | | | | | | |
| Engineering Chemistry | 4+2 | | | | | | | | | |
| Engineering Drawing | 3+2 | 0+4 | 0+2 | | | | | | | |
| Mathematics | 4+4 | 4+4 | 3+3 | — | — | — | 4+4 | | | |
| Electrotechnics | | 4+2 | 3+2 | | | | | | | |
| Mechanics | | 2+2 | 3+3 | 3+3 | — | — | 3+3 | — | 4+4 | |
| Material Technology | | | 4+1 | 3+2 | 3+2 | | | | | |
| Economics of Enterprise | | | | 3+3 | | | | | | |
| Machine Parts (Mechanical Design) | | | | 4+3 | 4+6 | 4+6 | | | | |
| Thermodynamics and Fluid Mechanics | | | | | 4+3 | 4+3 | 4+2 | 2+2 | | |
| Industrial Management | | | | | | 3+2 | | | | |
| Frameworks | | | | | | | | 4+2 | | |
| Contemporary Physics | | | | | | | | 3+1 | 3+1 | |
| Automatic Control | | | | | | | | | 4+2 | |
| **Specialized Courses** | | | | | | | | | | |
| Analysis of "Machine" and its mechanisms | | 4+2 | 4+2 | 4+2 | | | | | | |
| Service and Maintenance of "Machine" | | | | | 4+2 | | | | | |
| Manufacture and Repair of "Machine" | | | | | | 4+2 | | | | |
| Design and Research of "Machine" | | | | | | | 4+6 | 6+9 | 3+9 | |
| Diploma Work (Theses) | | | | | | | | | | 36 |

Digits show hours per week (lecture + practice) (15 week terms).
Depending on choice the "Machine" can be "Automobile", "Railway Vehicle", "Ship", "Airplane", "Building Machine", or "Materials Handling Machine".
After the 6th semester the students may apply for Industrial Engineer's Degree.

he should take advantage of opportunities offered and specialize according to object at the start of his instruction.

Our algorithm shows that technical problems are introduced as examples of application in the second cycle. However, several engineering fields (e.g. mechanical engineering) comprise ranges of objects to be considered which are particularly wide: from the vacuum cleaner to the ocean liner. Thus, from the point of view of didactics, one would be making a serious mistake if he were to take examples of application haphazardly from different objects because he would never be able to familiarize himself with the subject as a whole, with its multifaceted but nevertheless interrelated problems. His knowledge would be like a mosaic in which the individual pieces did not form a comprehensive picture.

A further disadvantage of this approach for the selection of objectives would be that it would spoil the efficiency of instruction, because the student would have to familiarize himself with too many data and descriptive attainments in order to understand the gist of the problem. Unfortunately, it is precisely these data and attainments that become obsolete very rapidly. Therefore, the student should be burdened with them only to a limited extent. A minimal burden can be supported if the problems and examples given always refer to the same object (e.g. the automobile), knowing that the student, who has taken his degree in engineering, may never in his life deal with automobiles. Nevertheless, the automobile will have filled its function, for the student will be able to make good use of all knowledge and skills he has developed in connection with the automobile in any other fields of mechanical engineering.

Here we should point out that in the educational process the student should sometimes be offered more than one "practice field" from which to choose. Of course, any choice of any field is in some sense a specialization in education. But a specialization can be a real one or only an apparent one depending on the breadth of general knowledge which is required to solve all the problems in the given field. The aircraft, for example, is a very good "practice field" in mechanical engineering because all kinds of theoretical subjects can be linked to it through its role as an example of application. Such is not the case for cranes or for textile machinery as they are hardly suitable for the application of aerodynamics or of heat transfer.

One should also note that if a student must choose a practice field, he should do so at an early stage of instruction. This statement shocks many people who believe that even specialization by object should be postponed until as late as possible. We are firmly convinced that delaying this so-called "practice specialization" is pernicious not only because doing so gives the curriculum a deductive structure, with all its negative consequences, but also because it increases the disadvantages of specialization.

We must also consider the fact that the timing of the inevitable specialization by object has a strong influence upon the mind of the student. If specialization by object occurs at the end of instruction, his intellectual horizon *narrows* step by step; in the last term, every subject will be centred around a restricted topic. If specialization (by object) occurs at the start of instruction, the student's intellectual horizon will be *constantly widened*. Even in the final term most of the subjects will impart general knowledge; only during their application will the selected object come up. This approach is quite different from a qualitative point of view.

In the case of a deductive curriculum, the newly qualified engineer is led to believe that he has become a specialist, while in the other case, he has learned that he can deal with many different kinds of fields.

In the first case, the student only has the object in view; in the second case, he realizes that specialization by object is merely a means to an end: *a tool and not a goal!* The situation is quite different in the case of specialization by activity. Instead of acting with precipitation, the student should put the final decision off as long as possible. We have already mentioned that the activity, in contrast to the object, must be in harmony with aptitude. But how can a first-year university student know what skills he will need for any particular activity? Moreover, he probably does not yet know what his own aptitudes are.

It is also important that the development of those skills requiring a great deal of time for mastery be started at the beginning of instruction, along with the development of knowledge. What skills should be developed first? In other words, what sorts of activity should students engage in at the beginning of their studies? In the case of engineering education, we should start from the fact that one activity existing in the hierarchy of engineering activities represents the final link in the chain, the real purpose of all other activities. This activity is known as utilization and exploitation; operation and upkeep. Even a first-year engineering student should practice it, regardless of the specialization he will choose later in his studies.

This activity will enable him to gain a good grasp of problems, to see things in their correct perspectives — this being necessary for the development of his attitude. Whether he will be a designer or a calculator, an organizer or a researcher, he must, as an engineer, be able to perceive the ultimate goal: that his work give rise to the functioning, the worthwhile use, of something, somewhere, for the good of mankind. He must know the requirements of a given operation and take them into consideration, from the inception of the idea, through its planning, to its realization.