

High School (AHS) and University from an Engineer's Perspective

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Prophecies of the decline of European culture and laments on the diminishing quality of university students have proven to be wrong. On the contrary the most valuable asset in Europe's development has been the quality of its youth. In order to stimulate and develop talents, problems in general education, problem solving abilities and communication abilities have to be tackled. The paper addresses these problems.

INTRODUCTION

IN ORDER to maintain the current level of technical systems, some 100 000 highly qualified experts, organizers, inventors, and engineers are required. Creative people have been educated for years at great expense in order to meet these demands. For 50 years the best talents among the young of the white peoples have had a special affinity towards the profession of an engineer. Already during childhood boys take up technical subjects. The urban societies and families, steeped in prosperity and the tradition of an open-minded and sophisticated culture, provide young people capable for this special profession. They represent the elements for the development of a very mature product—the technical approach. It is still represented in all industrial countries with old-established and highly developed industries.

However, times have changed—Faustian thinking has had about enough of technology. Fatigue and a special kind of pacifism, pacifism in the battle against nature, is spreading and there is a new turn towards a proximity to nature. People practice sports instead of technical skills, they hate the big cities, they want to escape from soulless activities, from slavery to machines, from the clear and cold atmosphere of technical organizations. In particular, the great and creative talents are now turning against practical challenges and the sciences and turn to speculations. Occultism and spiritism, Indian philosophies, metaphysical brooding of Christian and pagan varieties discarded since the advent of Darwinism, are now resurfacing. All this resembles the spirit of Rome during the reign of Augustus. The world weary are seeking refuge in primitive civilizations, globe trotting and suicide. The flight of the leaders from the machine com-

mences! Only second rate talents will soon be left, the last representatives of a great past. Major industrialists notice this decline of mental qualities of the younger generation. However, the great technical developments of the 19th century were only achieved by the steady improvements in mental abilities. For not only decline, but also stagnation is dangerous and heralds an end despite the willingness of highly trained staff to do work.'

This statement is not new but was published 58 years ago by the prophet of decline, Oswald Spengler, under the title 'Man and technology' [1] and has—apart from publishing date and style—a very current ring to it; cultural pessimism is a chronic European disease and, apparently, cannot be eradicated.

However, evidence objectively presented would refute Spengler and his present-day followers. The decline of Europe proclaimed by this prophet has turned into the 'Triumph of the Occident' as viewed by the historian [2]. Nevertheless, this view of disaster and prophecy is still very attractive and even lucrative. There are many attempts—supported by publishers—to make a hasty deal with panic for profit before final disaster strikes. Unfortunately, education has also become a victim of this attitude: teachers are loudly proclaiming the decline of educational standards, the poor quality of high-school (AHS in Austria) graduates and students. They feel that the present is a catastrophic era, or at the very least that we have arrived at a point of no return. They do not realize that they threaten to spoil the young by spreading panic about the future; the older generation apparently propagates a self-fulfilling prophecy by destroying the expectations of the young. One must agree with Popper [3] who is continually fighting our cultural pessimism and says 'It is obligatory not to pose as a prophet' and warns against 'the nagging prophets of pessimism'.

What do the actual developments in the past 20 years reveal?

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From the point of view of a professor of technology one observation is constantly being confirmed: the performance of young people studying technology is steadily improving. This happy observation is not, however, universally true but is valid for about 20 per cent of the highly gifted students. Admittedly the other 80 per cent are also important. However, the élite pulls the middle ranks along with it and many of those who are talented advance during their studies or first working years to the élite. In any case, it is easy to verify that there is a continuing improvement in the quality of diploma theses and doctoral dissertations: today there are, relative to the number of students, many more top-level academic publications and results than in the past. Notwithstanding this statement, the existing serious gaps and problems should not be ignored; but the distorted image needs correction.

Even great deficiencies and serious problems can be corrected and solved in principle. According to Popper's 'piecemeal engineering' [4] it is recommended that one should avoid serious mistakes and not be afraid of small mistakes, but learn from them in order to make gradual improvements.

How could such improvements be achieved in the high-school system? From the point of view of a professor of technology three areas are apparent:

1. general education;
2. problem-solving abilities;
3. communication abilities.

In what follows, the possibilities of improvements in these essentially inseparable areas are discussed.

1. General education

Detailed contents of general education programmes are always controversial. A few items are, however, quite essential. In balancing the orientation between *object* and *method orientation* in education, method orientation should be favoured, because there are just too many objects. Everyone knows the wrangling about teaching hours. How should it end if the amount of material to be taught is growing more and more? There is no alternative to method orientation, even at the expense of a high level of abstraction. A corresponding reform of education is very difficult and demands the full attention of teachers and pupils. For instance, physics demands a concentration on fundamental statements (e.g. conservation theorems), as demonstrated by textbooks (for example the textbook by Sexl *et al.*). Physics without objects is not teachable. A more efficient orientation on methods is, however, possible. One should not be too discouraged when high-school graduates have insufficient knowledge but have the capacity to close these gaps of knowledge if called upon to do so. The same could be mentioned in connection with the teaching of chemistry. It is likely that stronger method orientation needs to be applied in all subjects. The teaching of technology is highly neglected, for

which engineers and their professional representatives are responsible. Which engineer devotes himself to teaching, and even if he does, what of interest has he got to offer? In this country people are still considered as educated even if they proudly proclaim their ignorance of natural sciences or mathematics but especially of technological subjects. How can we resolve the problems of technology if this attitude prevails? Even when being critical towards technology, we should explore the root of this evil and try to improve it from the inside—by 'piecemeal engineering!'—simply because it is not possible to approach it from outside its area.

In the following section problem-solving capabilities are closely connected with these problems. The philosophical fundamentals of technology have to be treated in general education. The anthropology of technology in a very rudimentary manner belongs to the area of cultural subjects [5–8]. This subject could be placed between the natural sciences and the humanities.

2. Problem-solving abilities

The greatest problem faced by high-school graduates in Austria when entering technical universities is the transformation of acquired knowledge to problem solving. If even excellent pupils have problems in this matter, a deficiency in teaching must be responsible. Herein lies one of the reasons for the high drop-out rate of students.

As the process of knowledge-transformation is a creative act, it is not simple to teach, but creative potentials can be stimulated. A creative person—and there are a lot of them (perhaps all mentally sound people are creative)—has to be challenged in order to develop his talent. Therefore, for instance in teaching mathematics, the deadly formalism of arithmetical exercises may be supplemented by vivid applications, for example in physics. And after all, the central aim of any teaching is to uncover creative potentials, to stimulate them, and bring them to the surface. An obstacle to this implementation is the prejudice of those who think that creativity is only possible in their own area of activity. One is also hampered by tradition, which abhors innovations and prefers reproduction to production. Every serious study of creativity reveals that creative processes in art, technology and science are very similar. According to Rothenberg's observations [9] creative ideas are mirror-images of dreams arising from the subconscious, which are, however, tested by reality. The traditional disregard of creative achievements shows not only a special liking for reproductions, for example in music, but also leads to parochialism, such as the lamentation about the 'typical Austrian inventor's fate', which is, of course, failure. Fortunately, reality is much better. Our economy gains from creative results and we have some important and successful inventors. There is nothing against telling high-school pupils about the highly talented Josef Madersperger (1768–1850), the inventor of

a sewing machine, and to discuss the reasons for his failure. However, why should he represent the typically Austrian inventor's fate, and not the successful pioneer of textile machines, Ernst Fehrer (born 1919), who is still working creatively, at over 70 years of age, in his prosperous factory in Linz?

One basic aim of school should be to motivate pupils to do creative work and not to demotivate them. However, it is important to recognize that, while the creative process includes play, it also requires knowledge and discipline. Within this tension-stressed triangle between creativity, knowledge and discipline the teacher has to move and apply the full range of his experience to show the way for which there is no singular path.

3. *Communication abilities*

Under this heading there are numerous topics, among them:

- ability for teamwork
- ability for interdisciplinary work
- ability to overcome hierarchic barriers
- knowledge of languages

These items are commented on in the following.

It is a truism that teamwork is very essential in industry nowadays. Division of labour has been developing since Taylorism and has been ethically motivated from the beginning of the Machine Age in the sixteenth and seventeenth centuries, very much in the sense of the Apostle Paul: 'There are manifold talents but only one spirit.' The use of manifold talents for one goal represents an educational value. Working in groups in training, however, is not without its problems, because it is not supposed to eliminate individualism but rather to help the individual to develop; it should not eliminate competition, but regulate it; it should not conceal weakness, but rather compensate strengths. Working in groups does not eliminate learning stress but raises efficiency, and it should create satisfaction for individual and common achievements. It would be advantageous for projects in the upper classes of high school to be implemented in working groups. Also at universities, a project-orientated teaching is possible; however, it demands high teaching skills and is very expensive. Thus, a realization on a broad scale will not be possible, but it is necessary to follow any good idea and use all opportunities.

There is a connection between interdisciplinary activity and working in groups, and perhaps there is also a contradiction. Working in groups should not degenerate into overspecialization, and interdisciplinary activities should not be limited to one-sided cooperation. Interdisciplinarity is to be demanded from the individual. It is necessary to find a balance

between specialists and generalists; it is not an alternative between knowing nothing about everything or everything about nothing. Interdisciplinarity promotes creativity and must not be a substitute for quality. For the upper classes of high school, it is therefore recommended to offer alternatives for the highly qualified talents who tend towards early specialization. It is also recommended that for the average pupil complementary subjects be offered in order to avoid early specialization.

Hierarchical structures are found everywhere in professional life. Hierarchy means, among other things, order and discipline, which are necessary in a society. The success of a hierarchic organization strongly depends on the ability of communication between the various levels of the hierarchy. Normally the flow of communication is directed from the upper to the lower level. Difficulties are produced, however, in the opposite direction—orders have more authority than recommendations. Every hierarchic level acts as a filter for information coming from the lower and destined for the upper level. This censorship represents an unfavourable, antisocial situation and diminishes the efficiency of the organization. (Censors themselves claim, of course, the contrary!) Education by the parents and the school is very important in eliminating this unfavourable situation. Self-confidence, the ability to express one's own thoughts, the reduction of shyness in self-representation, other personality-forming activities, all these are special pedagogical strategies in each subject.

Austria is pushing towards membership in the European Community. This is only one argument to promote the teaching of foreign languages. In Austria the knowledge of foreign languages is at a much lower level than in The Netherlands, or in Switzerland where more than one mother tongue is spoken. How enriched is one's own culture by understanding the foreign!

It is hard to understand that our schools have not concentrated on this crucial point, in particular when considering its geopolitical location. Besides English as the lingua franca, the learning of a Slavic language would be worthwhile. The economic and cultural advantages are obvious in connection with the political opening of the East.

FINAL REMARKS

This paper does not represent a magic formula to reform the AHS structures, even if this engineer has accumulated more than two decades of teaching experience. But these experiences may be interesting for some people, not to act as guidelines—this would be presumptuous—but as a stimulation for further discussion.

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The insight is equally as relevant as it is...
 pendence...
 where technology, even in its most complex...
 is by no means free from non-technical...
 decisions.

Given the choice, many engineers would...
 IN RECENT years, engineers have come to enjoy a...
 much higher status of self-esteem. Although still...
 subject to the German tradition of nose-thumbing...
 technology and applied science, the engineer is...
 secure in the knowledge that his efforts will flow...
 to history or be deleted in the word "dead end," eco-...
 nomic jargon, which is used with severity or...
 hesitancy, was largely due to engineers. The...
 clarity of his plans is clear, however, with the...
 growing shadow of doubt, indifference and tri-...
 tany concerning technological progress. It is not...
 factoring in the work of the engineer, but...
 engineers, who in their own way are working in...
 groups, which they have taken to call "brain...
 detachments" or "brain trust" or "brain units" or...
 they withdrew to the more neutral position of...
 simply being with the team and going to do...
 their jobs. This is not to say, however, that the...
 "brain trust" has already been broken. As long...
 change, more and more engineers are taking a...
 growth in their own sense of responsibility...
 It would certainly be unfair to suggest that manag-...
 ers and other professional groups are unaware of...
 this. The problem is that within the hierarchical...
 growth of institutions and corporations, the indi-...
 vidual is subject to such intense pressure that his...
 own sense of personal responsibility tends to get...
 buried. At the same time, only within the responsi-...
 bility for the given field of endeavor in which...
 he has the power and authority to act, the individual...
 becomes free, and always within the ultimate...
 responsibility for decision or action, is effec-...
 tively diminished, with the course of some force...
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To take the problem of social and ethical respon-...
 sibility seriously, which means more than simply...
 coming out with platitudes in the presence of the...
 engineer, technician and technical institutions...
 must be thoughtful and very new questions...
 and answers. Progress will not be made until...
 we have a new way of thinking about the world.