An engineering education response to a globalising world

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ABSTRACT: In August 2002, the Engineering School at Telemark University College, Porsgrunn, Norway, commenced a nationally supported pilot project on recruiting vocational school graduates holding a relevant trade certificate to its electrical, electronics and control engineering department. Earlier, vocational school graduates would have had to spend one academic year or more in the study of mathematics, sciences and languages to be considered eligible for admission. The principle of academic equivalence, with respect to the Education Act, is underlying this project. To make this principle work, the School, and not the students, had to change. After seven years of operation the admission is competitive, the academic results appear satisfactory, the retention has been improved – all resulting in a better college economy. These benefits at present seem to outweigh the administrative challenges of running two parallel and different types of classes.

INTRODUCTION

In April 2002, the Norwegian Ministry of Education and Research (the Ministry) permitted Telemark University College (TUC) to carry out a pilot project on recruitment from vocational schools, commencing in August, 2002. This project was a response to industry's demand for engineers better trained for mastering complex jobs in a dynamic international environment. Simultaneously, these engineers should, by graduation, be qualified for advanced studies at the Master and PhD levels.

However, the project challenged two education Acts, traditional learning forms, and course content. As engineering education is controlled by the Ministry, the radical elements underlying the project had to be accepted by the Parliament. For that reason, seven years elapsed from the 1995 TUC initiative to the commencement of the pilot class.

The project background, planning, implementation and results, starting with some legislative prerequisites for project realisation are presented in this article.

EDUCATIONAL CONSEQUENCES OF GLOBALISATION

From about 1970, Norway began to feel the effects of a globalising world. Early, it became clear that a country with a small population could not expect to compete successfully on quantity in a mass production market. Instead, it was generally agreed that it should be possible to compete on the export of human competence and quality products, especially for *niche* markets. To adjust to this challenge, it was also agreed that society, trade and industry would have to undergo a series of fundamental reforms. And clearly, in making such profound adjustments possible, it would be necessary first to reform the entire educational system.

During the following three decades, these ideas constantly were followed up by new legislation and reforms; many of them concerning the entire pre-college educational system. This article, however, will concentrate on the upper secondary level legislation and its significance for engineering education only.

In 1974, the National Assembly passed the Law on Upper Secondary Education. Spurred by trade and industry confederations, the law introduced the radical principle of ruling all upper secondary education programs, *including* vocational schools, by one common law. In 1994 and 2005 this law was amended to become the present Education Act [1].

The important part of the present Act that relates to the TUC pilot project is Chapter 1, *The Purpose and scope of the Act*, particularly Section 1–2, second paragraph. This section states that *Upper secondary education shall contribute to increased* *awareness and understanding of*, among others, *democratic ideals and scientific thought and method*. The requirement of emphasising scientific thought and method was introduced already in the 1974 version of the Education Act.

The first vocational training programme to comply with the new requirement was launched in Telemark in 1978, pushed by the process industry, which was in need of new methods for educating their process operators. In contrast to traditional vocational schools, these new programmes introduced a college form of organising the learning process and laboratory work, including student preparations and reporting. Also introduced were the principles of *systems thinking and the new teacher role* as an organiser and facilitator of learning, even outside the classroom.

Gradually, the basic ideas underlying these programmes were adapted nationwide to all vocational school departments. Since the educational scope had moved from *doing by hand* to *systems thinking*, the titles of the skilled workmen often had to be changed accordingly. For instance, a *craftsman* became an *operator* or a *technician*. This development led to a surprising result: junior high school pupils with a special gift for technology and mathematics began to choose vocational training instead of traditional senior high school classes. Industry and trade confederations took pride in this development and quickly learned to appreciate the versatility of the new personnel. In some cases, these workmen competed effectively for engineering positions with graduates from the former two-year engineering colleges.

In 1994, an adjusted version of the 1979 learning plan was made *mandatory* for all trades. About the same time, programmes leading to trade certificates were incorporated in the vocational school and modernised by form and content. Most important, significantly more theory was added to the learning programme. Thus, the time had come for the TUC to work at changing the rules of admission to engineering education.

SEVEN YEARS OF PREPARATIONS, PROCESS AND PLANNING

Spurred by a general decline in recruitment and the success of the vocational school reform in August 1995, the process of changing the rules of admission was initiated by the TUC group of the Norwegian Society for Chartered Engineers (Tekna).

In the years 1995 to 1997, the Tekna initiative was firmly college-supported by the Dean, who immediately named an internal project group to prepare a formal application to the Ministry. Also, the positive feedback from the National Council for Engineering Education (NRI) spurred the work on the project. Eventually, the TUC application was rejected by the Ministry.

In the wake of the first wave of enthusiasm followed a four years' period (1997 to 2002) of network building and lobbying of parliament members. Networking included the NRI, two major national engineering societies, five international engineering education societies, and The Confederation of Norwegian Business and Industry. In cooperation with these societies and the Ministry, even an international conference on engineering education (ICEE 2001) was brought to the country to underline the need for development supported by educational research. Eventually, in January 2001, signals were given so that the TUC could resume its planning and write a new formal application to the Ministry.

However, while the Ministry was doing their executive work, the number of students continued to decrease. Consequently, the TUC Board of Regents had to prepare the closing of the Electrical Engineering Power Department. The decision would be made in their April 2002 meeting, tentatively.

Simultaneously, the TUC project was linked to a project conducted by the Electrical Contractors' Association of Norway, aiming at a similar goal. Quickly, more confederations and the Norwegian Air Force joined. Their joint efforts convinced the Ministry which, in an early week of April letter of consent, caused the Board of Regents to drop its closing plan.

Instead, a pilot project class of 36 vocational school graduates, each holding at least one relevant trade certificate, was started in August 2002.

TWO PILOT PROJECT PRINCIPLES

As the pilot project in some ways challenged traditional thinking and ways of action, it was anchored to two principles: *educational equivalence* and *quality assurance*. The first principle ignited and fuelled the project. The second was considered necessary for protection against political and collegial criticism and attacks. In other words, quality assurance meant simply a *tool* for sustaining the project.

Educational Equivalence

With a reference to the generally formulated Education Act's Chapter 1, Section 1–2, *entering student equivalence* became one key principle of the TUC process.

By law, only graduates from certain senior high school science departments were automatically eligible for admission to higher education. Due to the ruling *entering student equality* principle, graduates from all other departments were required to spend one college preparatory year at school or take a series of summer semester courses over a period of two to three years. To the TUC, however, *equivalence* meant that *all* students graduating from senior high schools were at an equivalent level with respect to preparations for academic studies. Else, the rules for admission would simply render the Education Act's Chapter 1, Section 1–2 meaningless.

A comparison between traditional and new thinking is illustrated in Figure 1. For both models, a vocational school graduate must have earned a trade certificate. It can be seen that both ways lead to an *equivalent* Bachelor's Degree in engineering. However, since they differ by one year of study, it may be asked: where is the equivalence?

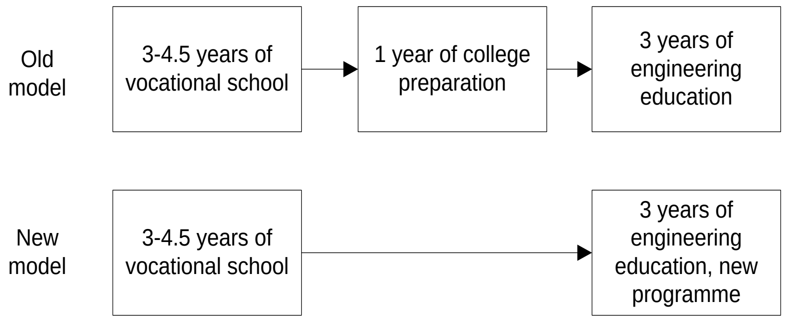


Figure 1: The *short-circuited* college preparatory year.

The answer is simple: *to comply with the law's principle of equivalence, not the students but the TUC itself would have to change*. The changes would both include the learning material content, as well as the learning process, to be successful. Since national laws and regulations prescribed that certain elements of general knowledge should be mandatory and mastered by any citizen, care had to be taken in the formulation of new goals and educational content. These mandatory elements include: advanced Norwegian and English, mathematics, physics and chemistry. How these elements were treated will be discussed in the next section, Vocational School Changes.

Quality Assurance by Scientific Evaluation and an External Project Steering Committee

The TUC's pledge to evaluate and document the pilot project by scientific evaluation introduced a principle of quality assurance that helped it to pass the Ministry.

Also, a Project Steering Committee was established, consisting of large industry confederations' representatives, the Air Force, the Superintendent of the regional secondary education system and the TUC Rector, to inspire the pilot project members. Other tasks were to finance, influence and control the project. Over the longer perspective, the Steering Committee should also help to influence secondary schools on the development of future collaborative learning programmes.

This quality assurance programme has resulted in four conference papers [2-5], four Steering Committee reports to the Ministry, several mass media interviews and articles. In 2008, the new programme for undergraduate engineering education (Y-VEI) was awarded the 1st prize in the Ministry's Quality in Education contest.

VOCATIONAL SCHOOL CHANGES

The important vocational school changes are represented by development of the teacher role and a learning programme built on the principle of course integration. As it will be seen, the modernised vocational school in several ways leads engineering education in the adaptation of recent pedagogical ideas.

The New Teacher Role

In traditional schools, and the vocational schools were no exception, teachers expected to teach the young generation their professional specialty. Thus, the goal was to teach a specific curriculum in a traditional way, which meant the use of lectures and exercises in classrooms and workshops as dominant teaching tools.

The new paradigm of 1979 introduced, above all, the teacher to the extra dimension of being the responsible organiser and leader of complex learning situations as, for instance, project work in groups. Today, a teacher working in this way is often denoted a facilitator, striving to master different tasks such as:

- Building cooperative networks between the school and companies within particular branches.
- Involving relevant branch confederations as observers and advisers.
- Designing a programme for learning in cooperation with external partners, colleagues and the Rector.

- Discussing learning objectives, content and methods with craftsmen (the factual teachers of the trade) in the cooperating businesses.
- Planning and carrying out a scheme for appropriate contact and student follow-up programmes during their periods of practical training outside the school.
- Planning and carrying out the student evaluation process.

To see the full effect of these changes and challenges, it had to take about 20 to 25 years, as one generation of teachers was gradually replaced by a new one. Typically, the new vocational school teachers were engineers at the Bachelor's level, simultaneously holding at least one relevant trade certificate. In addition, the requirements of new theoretical courses attracted teachers holding a Bachelor's or even a Master's degree in their fields of specialisation.

Applied Systems Thinking

The first year of vocational school introduces systems thinking as applied to two interconnected relationships: technology and society, as illustrated in Table 1.

Table 1: Systems thinking elements.

Technology	Impact on Society
Electrical, mechanical and control systems analogies.	Interrelationship between legislation, organisation, production, economy sustainable environment concern.

By examining the vocational schools' learning programmes, these elements were visible in two ways. First, they were expressed through the formulation of educational goals and actions. Second, they were found in the way in which structural planning, reporting and documentation requirements were directly related to the vocational school technical content.

Interpretation of Vocational School Transcript for College Admission Purposes

The study programme of engineering schools is based on the content of the senior high school's science department or equivalent. The strength of this common platform for entering students is its broad content of general sciences, including *traditional culture-* related liberal arts. Its weakness is the absence of technology and broad-scoped technological-cultural elements.

In transforming vocational schools' *interdisciplinary* transcripts into a readable form for the TUC, the European Credit Transfer System (ECTS) was used. The ECTS defines a completed undergraduate study as 180 ECTS credits of work. Since one year of full-time studies normally represents 60 ECTS credits, the Bachelor's Degree may be awarded after three years of study.

The examination of vocational school learning programmes related to electrical, electronics and control engineering identified a total of 33 ECTS credits learning material equivalent to TUC's introductory courses. In the ordinary engineering education programme, these 33 ECTS credits were, in reality, used to compensate for technological shortages of the senior high school science department and equivalent learning programmes. Thus, the 33 ECTS credits were used to compensate for pilot class students' shortages of general insight in languages, science and mathematics. In reality, the TUC was simply accepting technology as one of the cultural pillars of today's society and could formulate goals, plans and content accordingly.

Also examined was the organisation of vocational school learning, by inspecting educational plans and through interviews of vocational school teachers and leaders. It was noted that learning programmes were based on interdiscipline. Interdiscipline meant that vocational school pupils had to learn how the real world industry and businesses were organised and operated; for instance: planning, execution and results had to be reported in writing within a deadline. This way of thinking and working was accepted by the TUC as important social science elements in the learning process.

Table 2 shows how vocational school transcripts, containing relatively few traditional courses, were transformed into a readable form for the TUC. Credits for learning by interdiscipline are found for the courses *Environmental Concern* and *Electives*. Note that *equivalent* means vocational school course *content equivalence* to relevant TUC courses. Also, ECTS credits(-) and ECTS credits(+), respectively, denote vocational school credit transfer and credit substitution, making the TUC workload equal to all students, regardless of the learning programme.

Regarding the TUC courses in Engineering Mathematics and Physics/Chemistry, they are designed to comply with engineering culture principles. This means, where the formal content is concerned, the TUC programme abides by the requirements of the secondary school's science departments. However, factual content, problem selection, form and working style are in compliance with the pilot project students' experience of technological environments, engineering culture and practice.

Table 2: Credit transfer and substitution.

Course	Comments	ECTS credits(-)	ECTS credits(+)
Theory of Electricity	DC theory equivalent	3	
Analogue Technology	Equivalent to TUC introductory course	6	
Digital Technology	Equivalent to TUC introductory course	6	
Environmental concern	Learned and practised in the workplace	3	
Electric Power Plants	Includes AC and three phase theory	3	
Instrumentation	Equivalent to TUC introductory course	6	
Mathematics	Catching up with *ordinary* students		21
Physics			3
Electives	Social sciences applied in the workplace	6	
Advanced Norwegian	Written and oral business communication		3
Technical English	Written and oral business communication		6
	Total	33	33

Accepting Vocational School Courses – a Quality Reduction?

It is important to underline that the TUC did not, and does not, convert vocational school work into ECTS credits. The examination of vocational school learning programmes made it clear that vocational school course contents were often equivalent and even equal to introductory college courses. As a consequence, it became clear that course content quality could not serve as an indicator of educational quality. Instead, it was asked: *how can educational quality in a dynamic educational situation be expressed and documented*? The TUC's answer may be given in just a few words.

In general, academia has had a tradition of a slow rate of change. Under such circumstances, it was assumed that academic quality *may* be measured and assured by traditional means like, for instance, the student/teacher ratio, course content, professor qualifications by the time of hiring, teaching facilities, and so on. However, such criteria alone will hardly suffice in a *dynamic* environment. Under constantly changing conditions, teaching needs to be considered a *discipline*, protected and quality assured by educational research.

As a result of this thinking, the pilot project has been subject to quality assurance by educational research.

SELECTED PILOT PROJECT STATISTICS AND RESULTS

It has been mentioned already that pilot project results have been reported through engineering education conference papers. As an important result of this documentation, the Ministry has accepted vocational school equivalence and allowed additions to the rules for admission to engineering schools. Now, it may be asked: *what is the situation after seven years of class operation*? In the following, data on class size, retention and grade distribution will be presented and discussed.

Student Body Development and Retention

Student body statistics are presented in Table 3. In reading the table it should be remembered that the classes of 2007, 2008 and 2009 will graduate in 2010, 2011 and 2012, respectively.

Table 3: Student body development 2002-2009.

	2002	2003	2004	2005	2006	2007	2008	2009
Qualified[1] applicants	51	127	101	103	107	137	110	131
Competition points	None	38.0	39.7	41.7	40.0	43.5	39.6	36.8
Class size by 1 October	36	46	45	43	49	50	50	58
Class size by 1 October, 2009	-	-	-	-	-	51	50	58
Graduation class	26	36	42	39	42	-	-	-
Diplomas[2]	24	31	31	35	41	-	-	-

1. A qualified applicant must successfully have completed the vocational school and possess a relevant trade certificate.
2. All 180 ECTS credits must successfully have been passed, and the main project report accepted and presented before the graduating student can receive the diploma in three years.

Further, and as shown in Figure 2, retention has never been lower than 78%, which is significantly higher than < 70% for ordinary TUC classes. It is particularly interesting to note (Table 3 and Figure 2) that the number of diplomas issued is lower than the number of students who have successfully completed their main project: in the classes of 2002 – 2006 7.7%, 13%, 26%, 10% and 2.4% of the students respectively, did not receive their diplomas.

The reason: some students did not bother to challenge their final exam *F* grade(s), mainly because they had already accepted interesting job offers. It is believed that this lack of interest in a diploma may be blamed on the *hot* labour market situation for practising engineers in Norway. Consequently, several full-time students are having part-time jobs in industry and electrical contractor companies. Also, it is normal for senior-year students to be hired for permanent positions several months ahead of graduation. As a result of these facts, it is believed that the final diploma does not appear to be important, either to a significant number of TUC graduates or to some employers.

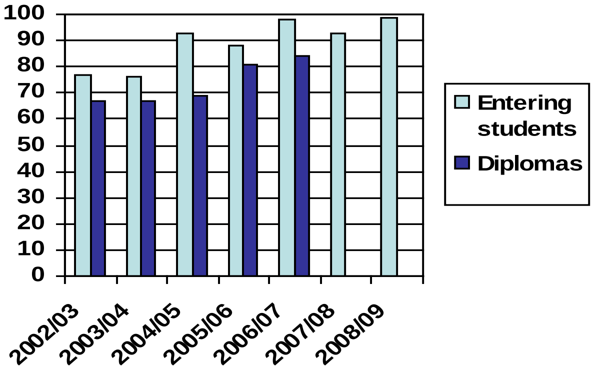


Figure 2: First-year retention and graduation diplomas. The ordinate is labelled in per cent (%).

Grade Distribution

By the start of their first semester, all pilot class students have stayed out of school for at least two years after being awarded their trade certificates. Figure 3 shows the distribution of grades for the very first class in the period 2002-2003 (1st year), 2003-2004 (2nd year) and 2004-2005 (3rd year). It can be seen that during the studies there is a shift of grades to the left, indicating a student adjustment to the learning environment of the class. However, Figure 3 also reveals that the grade improvement mostly must be due to the student drop-outs indicated in Table 3.

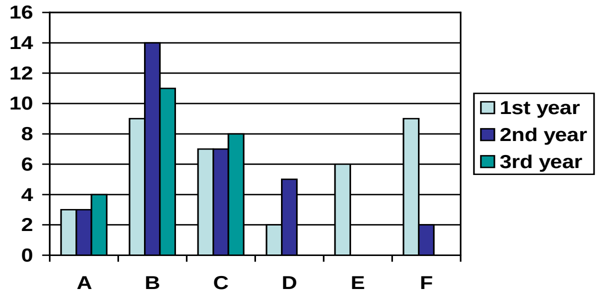
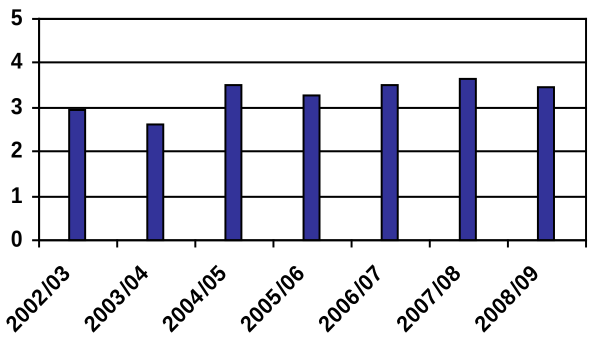


Figure 3: First pilot class grade distribution. The ordinate represents the number of students; the abscissa the six grades used in Norwegian universities and colleges. *F* is the only non-passing grade.



Grades
A: 4.5 to 5.0
B: 3.5 to 4.5
C: 2.5 to 3.5
D: 1.5 to 2.5
E: 1.0 to 1.5
F: 0 to 1.0

Figure 4: Class average GPR after first year of study; the ordinate gives the grades by numbers according to the list at the right.

Figure 4 shows the development of the average grade point ratio (GPR) after the first year of study for all classes since 2002. In a reasonably close relationship to the increased demand for admission competition points shown in Table 3, the bar graph may indicate a slight rise of academic quality, using grades as a quality indicator. If the GPRs are converted to letters, the average results are C (2003), C- (2004), B- (2005), C+ (2006), B- (2007-2008) and C+ (2009).

These results indicate that one of the underlying pilot project intentions tends to be satisfied: the pilot class students perform academically well.

PROJECT BENEFITS AND CHALLENGES

Benefits

It has just been shown that expectancies of a satisfactory academic quality appear to have been met by the pilot project classes. However, the benefits are numerous and span a multitude of spheres of interest. In Table 4 benefits are, tentatively, grouped into four categories: academic, college, student and society.

When looking at the left column, it can be seen that the TUC has now had indications that the pilot class students may be qualified for advanced studies, even abroad. Recently, it became government politics to stimulate undergraduate students to spend one semester at a foreign university or college to obtain some international experience. Thus, in the spring semesters of 2006 and 2007, seven fourth semester Y-VEI students achieved a B- average at South Dakota School of Mines and Technology, Rapid City, SD, USA. Further, in the spring semester of 2007, two fourth semester Y-VEI students successfully passed all exams except engineering mathematics at the University of Queensland, Brisbane, Australia.

Table 4: Some pilot project (Y-VEI) benefits.

Academic Benefits	College Benefits	Student Benefits	Impact on Society
- All students have a hands-on experience. - Better retention. - Satisfactory grades by graduation. - Satisfactory results for 9 students having spent one semester at Australian (2) and USA (7) technical universities. - Institutional and disciplinary proliferation.	- No closing of TUC engineering departments. - Collegiate despair replaced by enthusiasm. - More students; a 60 % increase from 341 (2002) to 546 (2009) has been recorded. - More students, better economy. - Better contact between college/industry and its confederations. - Higher prestige, as documented by the TUC winning the national student enterprise championship contest 2005, 2006 and 2007. - National recognition by being presented with the Ministry's 2008 Quality in Education Award.	- Hands-on experience is supported by theory. - Attractive to a much larger labour market. - Unusually high starting salaries. - Saving up to one year of college preparatory studies.	- In 2006, the pilot project inspired the Government to prepare a new law on lifelong learning [5]. - A straight path from vocational training to engineering education may contribute to bridging a *gap of prestige* between vocational and academic professions, considered necessary to face global competition from densely populated countries.

Table 4 shows that the Y-VEI project significantly and positively has affected collegiate attitude, enrolment, retention, college image and revenue, and academic standing of students. As seen in the *Students Benefit* column, Y-VEI graduates are well received in the labour market. It is of particular interest to note that TUC Y-VEI groups have done well in regional, national and international student enterprise (SE) contests. The titles and awards won are listed in Table 5. Note that the Telemark Innovation Cup is open and not limited to student enterprises.

Table 5: Student contest titles and awards won by Telemark University College by Y-VEI groups.

Contest	2005	2006	2007	2008	2009
European SE Best Selling Award Contest	1st				
Norwegian SE Championship Contest	1st	1st	1st		2nd
Norwegian SE Innovation Award Contest		1st	1st		
Norwegian SE Design Award Contest			1st		
Norwegian SE Leader for One Day Award Contest	1st				
Norwegian SE Nordea Entrepreneurship Award Contest		1st	1st		
Norwegian SE Economy and Account Award Contest					1st
Eastern Norway Venture Cup					1st /2nd
Agder Venture Cup			1st		
Telemark Innovation Cup			1st		

It is interesting to note that an idea initially considered a political challenge has now spread to the Agder University and five other engineering colleges. Finally, and indicated in the right column of Table 4, the pilot project principles of *educational equivalence* and *documentation by educational research* now seem to have convinced the Parliament and the Ministry.

Challenges

As already mentioned, the Y-VEI concept has spread to other engineering schools. However, not all of them have tended to fully understand that realising the principle of *educational equivalence* means *college*, not student change. At present (2010), their *similarity* is seriously being questioned by the Pilot Project Steering Committee.

Today, the TUC pilot project classes exist in parallel with classes recruited in the ordinary way. Accordingly, the reverse side of the medal is represented by some duplication of almost similar courses – and more complicated, expensive and time-consuming planning work.

SOME FINAL WORDS ON COLLEGE SURVIVAL

Thus far, the project concept has proved itself academically, economically and professionally successful, and even spread to other engineering schools and disciplines.

The existence and future success of the Y-VEI concept may rest wholly on a continued TUC willingness to dynamically change engineering education content and form, all supported by local educational research.

It is a success at present, but only the future can show if the Y-VEI project will be sustained.

REFERENCES

1. The Norwegian Ministry of Education and Research, Act relating to Primary and Secondary Education. Education Act (1998), amended (2005), 15 March 2010, http://www.regjeringen.no/en/dep/kd/Documents/Legislation/lover.html?id=622
2. Clausen, T., Hagen, S.T., Hasleberg, H. and Aarnes, J.H., Recruiting engineering students from vocational school. *Proc. 6th UICEE Annual Conf. on Engng. Educ.*, Cairns, Australia, 285-288 (2003).
3. Clausen, T., Hagen, S.T. and Hasleberg, H., Recruiting competence from vocational schools: paradise regained? *Proc. 7th UICEE Annual Conf. on Engng. Educ.*, Mumbai, India, 199-202 (2004).
4. Clausen, T., Vocational school interdisciplinary as a key to success. *Proc. 2004 Frontiers in Educ. Conf.*, Savannah, GA, USA (2004), http://fie.engrng.pitt.edu/fie2004/index.htm
5. Hagen, S.T., Electrical Engineering Programme based on vocational school. *Proc. 2004 ICEE Conf. on Engng. Educ.*, Gainesville, FL, USA (2004), http://succeednow.org/icee/SessionIndex.html