Training materials, equipment, and teacher training in VET for e-vehicles

What can we do together when the vehicle sector is being digital?

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Content

Preface

The European motor industry is facing a major change through electrification and digitalisation. The technology shift means that vocational education and training for vehicle technicians at upper secondary level must adapt to new learning outcomes. This entails the need for equipment and learning materials that deal with function, troubleshooting, electrical safety, and repairs to electric and hybrid vehicles' electric propulsion systems. Six schools with automotive technical vocational training in Sweden, Norway and Estonia have worked together to map the type of teaching materials, equipment, and continuing education for automotive engineering teachers that are needed. Participating vehicle teachers have also explored what is possible to share locally, regionally, and transnationally.

Our common view is that good education and training cooperation brings great benefits. Collaboration also benefits upper secondary vehicle technical vocational education through new contacts and expanded networks. Vehicle training also benefits from high-quality education and more learners will probably complete the training as an effect. The European market for electric vehicles is growing and education and training needs to keep up with the demand.

What can we do together when the automotive sector is being digital? (2022) is the result of a cooperation project supported by Erasmus+. The partners have also held talks with the Swedish Confederation of Transport Enterprises, Motorbranschcollege, Bilfag, TTK University of Applied Sciences, ML Autoservice OÜ companies in the automotive industry and vehicle teachers in Norway, Sweden, and Estonia. The project and the report have focused on the following three issues:

1. What kind of teaching equipment do we need and what is possible to share locally, regionally, and transnationally?
2. What kind of teaching and training materials do we need and what is possible to share locally, regionally, and transnationally?
3. What kind of training for automotive engineering teachers training skills do we need for this major technological change and what is possible to share locally, regionally, and transnationally?

The project participants have discussed the subject of electric and hybrid vehicle technology that deals with function, troubleshooting and easier repairs of electric and hybrid vehicles' electric propulsion systems.

Another subjects was electrical safety when working on or near high-voltage systems in electrical and hybrid vehicles. We have carried out needs analysis, fact-gathering, idea development and recommendations, which are promoting learning outcomes in the subject of electric and hybrid vehicle technology.[1]

In the field of motor industry, VET providers are constantly grappling with rapid technological development. It is important for them to have access to both educational materials and current skills development.

The automotive industry emphasises the need for rule-bound follow-up, evaluation, and analysis to maintain quality and content that provide learners with the best possible prospect for obtaining work in the industry. At the same time, descriptions of course content relating to new technologies need to be made as open as possible, so that the course content can be updated on an ongoing basis considering the rapid technological development, at intervals of no more than three years. [2]

The aim is to provide a basis for pedagogical, didactic aids in e-vehicle VET and continuing teacher education and training in vocational education and training at upper secondary level.

[1] Electric and hybrid vehicle technology, Swedish National Agency for Education

[2] Training for a changing motor industry, Transportföretagen, Mats Lewan, 2021

Summary

The report proposes the following list of equipment and materials needed to conduct qualitative teaching in high-voltage vehicles:

- Basic modules for electrical engineering, exercise benches/stations for working with electrical engineering.
- Theoretical material for training in electric vehicles with both a theoretical focus as well as in a practical manner.
- Training materials for high voltage equipment such as powering down TSI boards.
- Electric vehicles that can be used when teaching in an accessible way, such as smaller vehicles where the systems are clearly visible.
- Electric vehicles with associated diagnostic equipment to be able to see functions and perform a diagnosis on the High Voltage part.
- Basic equipment for measuring voltage, insulation measurement, cordoning off electric vehicles and insulated tools for high voltage.
- Components to have in teaching such as high-voltage battery, AC compressor, electric motor, generator, powertrain, and charging station.

These requests probably look reasonably similar, and a variant of a sharing system should be available between upper secondary schools at local and regional level so that an individual VET provider does not have to acquire all the material themselves.

Continuing education for automotive engineering teachers

Our mapping of continuing education for automotive engineering teachers points to a desire for more knowledge in electrical/diagnosis and high voltage, how to handle new teaching and training equipment correctly; as well as how to work in a didactic or pedagogical manner in the teaching of learners in high voltage and Electricity/diagnosis. Knowledge of security and the allocation of responsibilities are areas that need to be strengthened.

Collaboration to strengthen vehicle training

Finally, the report proposes some areas where it is possible to collaborate locally, regionally, and transnationally to make it easier for the automotive upper secondary education and training institutions to conduct quality teaching in high-powered vehicles.

It is likely that e-vehicle education and training can strengthen its ability to achieve quality education when VET providers share teaching and training know how, theoretical material, equipment, and didactic approaches in the education and training of future technicians for electric and hybrid vehicles. Planning the various educational elements schematically enables a sharing system of resources between them.

Background

The European motor industry is facing a major change through electrification and digitalisation combined with other technology shifts. The change is closely linked to the new conditions that are emerging for the entire transport sector through accelerated technology development for vehicles that are electrified. Automotive companies are on their way to becoming software companies, where modern digital competencies are central to success as well.

The technological shift means that vocational training for vehicle technicians at upper secondary level has adapted to new learning outcomes. It also entails the need for equipment and learning materials dealing with function, troubleshooting, electrical safety, repairs to electric and hybrid vehicles' electric propulsion systems.

Partners

Those of us who worked on this report

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- Pär Winther, teacher in vehicle technology, specialising in Electric Passenger Cars, Erikslundsgymnasiet, Sweden,
- Keijo Sipinen, teacher in vehicle technology, specialising in Electric Power Trucks and construction machines, Nyköpings gymnasium, Sweden,
- Margus Kivi, teacher of Automotive Engineering, Specialising in Electric Passenger Cars, Kuressaare Ameticool, Estonia,
- Ave Paaskivi, coordinator, Kuressaare Ameticool, Estonia,
- Stig Mårstad, teacher in vehicle technology, specialising in Electric Passenger Cars, Byåsen videregående skole, Norway,
- Roger Rosmo, manager for technology and industrial subjects, Byåsen Videregående skole, Norway,
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- Henrik Larsson, teacher in vehicle technology, specialising in Electric Powered Trucks and construction machines, Bäckadalsgymnasiet, Sweden,
- Patrick Ärlemalm, CEO and project coordinator, Amledo & Co AB, Sweden.

A warm thank you for participation is also addressed to:

Tomas Tärnfors, Industry developer skills supply, the Swedish Confederation of Transport Enterprises,

Marcus Ölin, Industry developer Motorbranschcollege, Sweden

Mats Lewan, writer with a focus on technology, Sweden

Patrik Eriksson, former teacher of vehicle technology, trainer at Promeister, Sweden

Stefan Lust, former teacher of automotive engineering, Head of Education university/ polytechnic, Promeister, Sweden

Mr Henri Venniuas, Tallinn University of Technology, Estonia

Mrs Lauro Kesp, Tallinn School of Mechanics, Estonia

Vehicle teachers in VET and experts at Ystad gymnasium, Sweden, Nordenbergsskolan in Olofström, Sweden, Westerlundska gymnasiet in Enköping, Sweden, Yrkesgymnasiet in Gävle, Sweden, Jacobsskolan in Hässleholm, Sweden, Valgamaa Vocational Training Centre, Estonia, Tartu Vocational College, Estonia, Rakvere Vocational School, Estonia, Tallinn Lasnamäe School of Mechanics, Estonia, Viljandi Vocational Training Centre, Estonia, Tesla Motors, Trondheim, Norway, Motortrade AS, Trondheim, Norway, Opplæringskontoret for Bilfag Trondheim, Norway, Network for technology subjects, Trøndelag, Norway.

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Method

The report is based on the collection of information from participating vehicle teachers, observations made at schools, workshops in Norway, Estonia, and Sweden, and dialogues with industry representatives. Analysis and recommendations are based on the information gathered and the proven experience of the participants. Questionnaire responses with specified alternative answers in multiple choice questions from vehicle teachers were also a source of information and the reports *Education for an engine industry in change* from Swedish Confederation of Transport Enterprises, Electric and hybrid vehicle technology, the Swedish National Agency for Education, *Industry practice -safe handling of vehicles with high-voltage systems*, Bil Sweden. Background information for the development of the electric car market is also obtained from *the Political Programme for Norwegian Electric Vehicle Innovation 2021 – 2023*, Estonian *Vehicle Dealers and Services Association* (AMTEL) in Estonia, but not referred to in this report.

Presentation of equipment and material needs and suggestions on what can be shared locally and regionally in Norway, Estonia, and Sweden

As the automotive industry moves more and more towards electrified, digital, and connected vehicles, the need to understand and be able to get help with how to convey significant knowledge to learners has meant that the need for new training and education equipment and material has increased drastically

Norway

Examples of requested and existing equipment and materials at Byåsen videregående skole in Norway.

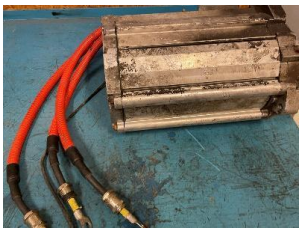
Compilation of equipment needed to conduct qualitative teaching in high-voltage vehicles. These examples are prepared by participating vehicle teachers at Byåsen videregående skole in Norway.

- Electric car for training

- Training model for hybrid vehicles

- Electric car parts for measurement



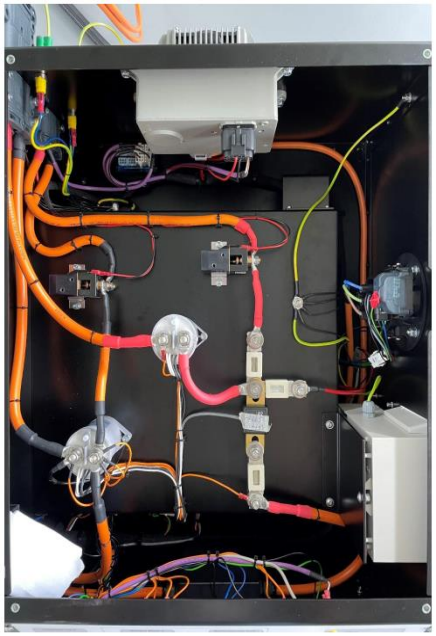



- Digital Communication - Can-Bus

Picture: Instrutek.no

- Christiani Training module for electric car – Complete powertrain

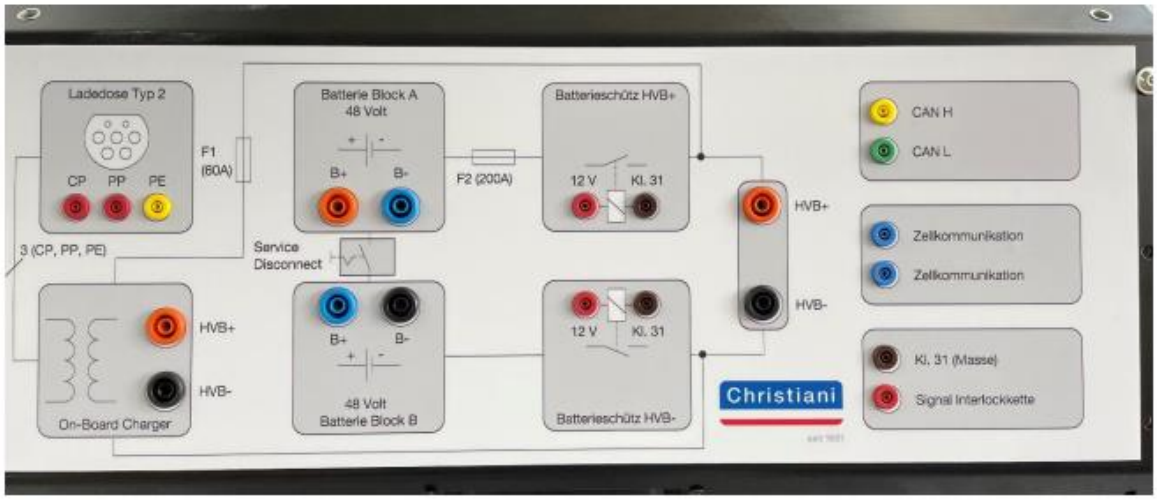
HV battery of the control and power supply module



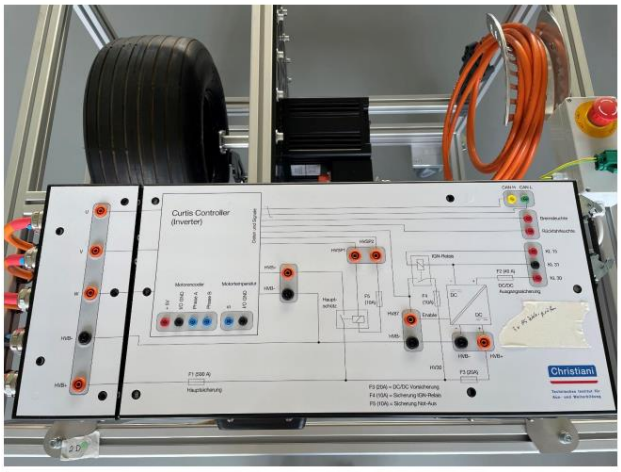
Functional model of e-drives and HV systems in motor vehicles

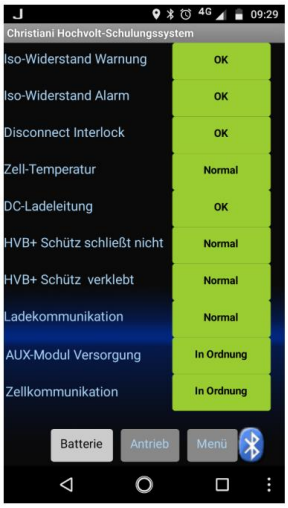
Control and power supply module

Measuring field power supply module

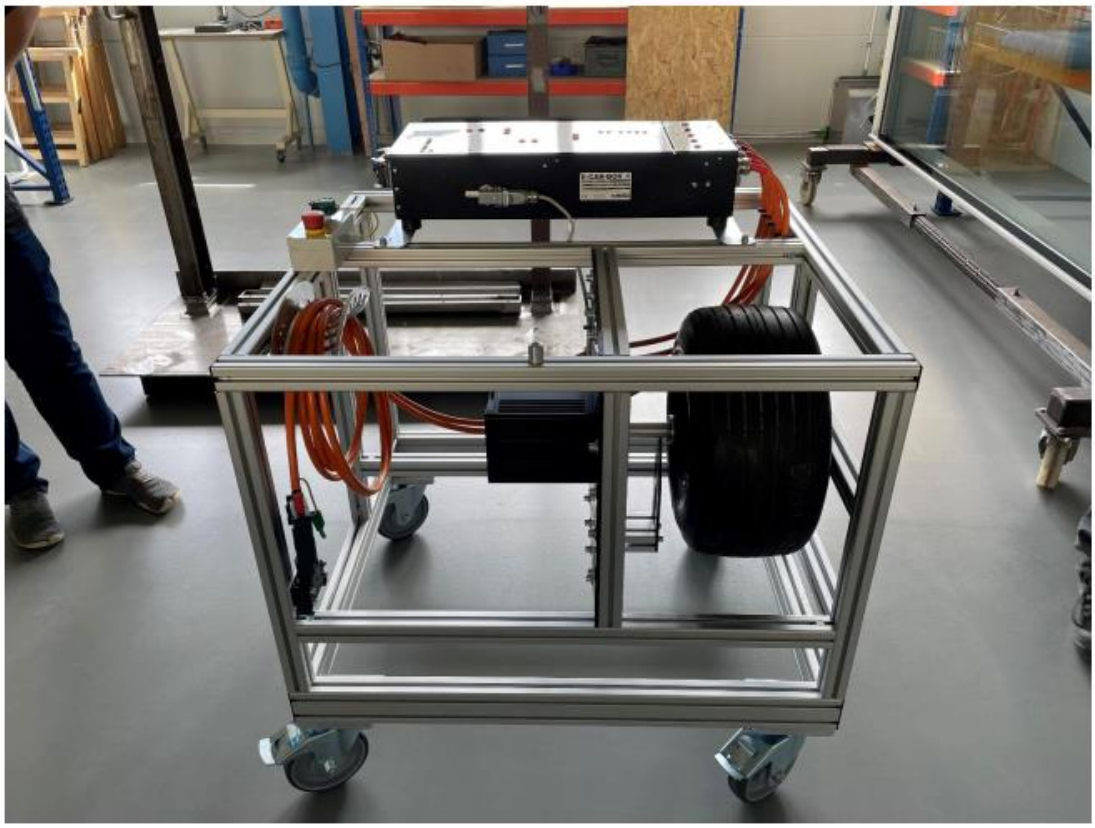


Measuring field for motor control





Drive module with motor control



In Norway, there are no central requirements from the authorities for repairs and expertise for electric cars. Each workshop is responsible for ensuring that all mechanics have sufficient skills to carry out repairs on vehicles with electric propulsion and high-voltage systems. It is important to be able to access technical information from the different car manufacturers on how the individual car can be rendered voltage-free, so that safe repairs can be carried out. There are some websites with information, such as NFPA - Emergency Response Guides for Alternative Fuel Vehicles, which are basically based on the safety of emergency services.

Curriculum and teaching materials in Norway is currently being developed by the individual school and there is a simple digital solution for a common database for all vehicles that also concerns safety around working with vehicles with high voltage. This is desirable from an educational point of view. The car app (app.bilfag.no) is available, but this one is very general, see annex.

Many of the learners have challenges with reading and writing but can still become very good mechanics. [3] Therefore, it is important that multimodal teaching programs are developed with good films and animations describing the subject, and not just text. In electrical science, various VR and AR solutions have been developed for safety training, and this should also have been considered within the e-vehicle individual brands and models. Developing such software can be costly, but with today's technology and quality of such equipment, it can provide a real undergraduate degree, where our learners are allowed to undertake basic safety training in a safe environment before performing the same task on vehicles. This type of teaching also makes it easy with larger groups of learners, even if we do not have sufficient teaching equipment and electric cars in the workshop.

Byåsen Videregåendeskole has developed its own teaching material for e-vehicle teaching that includes introduction to; History of electric cars, buy advantages in Norway for electric vehicles, Sales development of electric cars, Price, Environment globally and pollution locally, Policy blueprint Kia (AC engine), Battery types, DC-AC inverter, Principle of renewal, Engine types, Gearbox, Charging types, Hybrid, Kraft from two sources, service, and diagnosis.

Proposals for teaching materials and equipment that offer collaboration opportunities between vehicle training, companies, and trade associations by Byåsen videregående skole in Norway.

These proposals have been developed by participating vehicle teachers at Byåsen videregående skole in Norway.

Teaching materials can easily be shared between schools and countries, as there is good software, and there are tools for translating text into the different languages. A sharing portal should be developed, where teaching materials can be easily shared, sorted by safety management and the individual e-car products and models.

Sharing models and learning equipment are a bit harder, because of the long distances, and the equipment size. Byåsen videregående skole have established a specific teaching arena for

[3] Roger Rosmo, Subject Leader for Technology and Industrial Subjects, Byåsen Videregåendeskole, Norway

high-voltage vehicles, and we think that the best outcome for teachers from other schools will be to get their education at our school. The only downside is that the teachers are educated about using equipment they don't have at their own school at that moment, but maybe they will get in the future. Also, we are open to students from other schools who want to immerse themselves into high-voltage vehicles to join their teachers and use our teaching arena.

We can also offer our teaching arena to other schools and invite experts to teach.

Estonia

Examples of requested and existing equipment and materials *at Kuressaare Ameticool in Estonia.*

Compilation of equipment needed to conduct qualitative teaching in high-voltage vehicles. These examples are prepared by participating vehicle teachers at Kuressaare Ameticool in Estonia.

- Electric vehicles
- Hybrid vehicles
- Study stands for electric and hybrid vehicles

- Individual components (battery, gearbox, electric motor, etc.)
- Measuring instruments (multimeters, etc.)

- Tools for electrical work

- Factory manuals for vehicles
- Manuals for study stands

In general, Estonia uses all the material from the Estonian prodiags (www.prodiags.com) study programme. This material is interactive and is a payment service that cannot be shared free of charge.

The Estonian vehicle workshops believe that it is necessary to teach learners the general safety rules of electric and hybrid cars and to understand how electric cars work. Direct brand-based knowledge is not the most important thing. At the same time, some companies in Kuressaare admitted that they have so few electric and hybrid cars that they have no problem with them

yet. They cannot therefore name skills that car technicians should know about electric and hybrid cars.

Internationally, we have received a lot of material in this project from both Swedish and Norwegian colleagues, for example, we now use Tech Academy's study material in teaching. They have a much larger amount of teaching materials compared to Estonia.

Kuressaare Ameticool, examples of the need for teaching materials

1. Teaching materials are missing for the practical exercises. We don't have spreadsheets for e-vehicle measurement results.

2. There are no theoretical tests to check the learners' understanding after completing the theoretical part. It is desirable to have access to a single set of theoretical material with accompanying workbooks for learners with attached spreadsheets and tests to check learners' knowledge.

Proposals for teaching materials and equipment that offer collaboration opportunities between vehicle training, companies, and trade associations by Kuressaare Ameticool in Estonia.

These proposals are drawn up by participating vehicle teachers at Kuressaare Ameticool in Estonia:

At the local level, we can collaborate with companies, but they lack the resources to provide more theoretic model-based knowledge that is desirable.

There are 12 vocational schools with vehicle training in Estonia. These schools have access to the following equipment and teaching materials for theoretical and practical training for electric and hybrid cars.[4]

• Schools with both study stands and vehicles (5)

[4] Margus Kivi, Teacher of Automotive Engineering, Specializing in Electric Passenger Cars, Kuressaare Ameticool, Estonia

• Schools with only study stocks (3)

• Schools without any thing (4)

It is possible to share some of the equipment with each other because the training of electric and hybrid vehicles does not take place all year round, but rather for a short time. In addition, vehicle teachers and learners can receive continuous education and teaching at one of these schools for a few days per year and do intensive studies of electric and hybrid cars there.[5].

We could cooperate in different ways:

1) Collaborators who have electric and hybrid cars and have more knowledge can do some online classes and others can follow them and learn and can ask questions.

2) Cooperation partners who have more experience with electric and hybrid cars could come, to teach teachers and learners at another school for a week or more.

3) Since the quality of teaching also largely depends on the teaching tools, the best way to educate other teachers would be to be a job shadow. Again, other teachers could be shadowed by more experienced cooperation partners to acquire new learning skills and experience in dealing with electric and hybrid cars.

Sweden

Examples of requested and existing equipment and materials *at Bäckadalsgymnasiet, Uppsala Yrkesgymnasium Ekeby, Erikslundsgymnasiet and Nyköpings gymnasium in Sweden.*

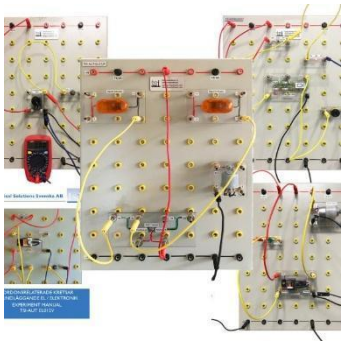
Compilation of equipment needed to conduct qualitative teaching in high-voltage vehicles including electric trucks and construction equipment. These examples are prepared by participating vehicle teachers at Bäckadalsgymnasiet, Uppsala Yrkesgymnasium Ekeby, Erikslundsgymnasiet and Nyköpings gymnasium in Sweden:

[5] This mapping of collaboration opportunities is a result of What can we do together when the vehicle sector is being digital? Erasmus+ 2020–1-SE01-KA202-077795 with the support of Erasmus+

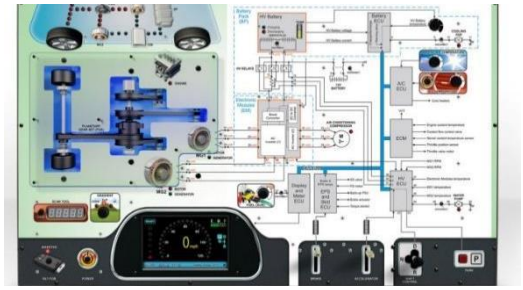
- Electric vehicle in compact format

The car's high-voltage system belongs to the lower scale of the voltage range of high-voltage vehicles. Only 51V AC and 72V DC and have the same basic structure as all AC electric battery vehicles. A teaching and training object for practical work with high-voltage vehicles.

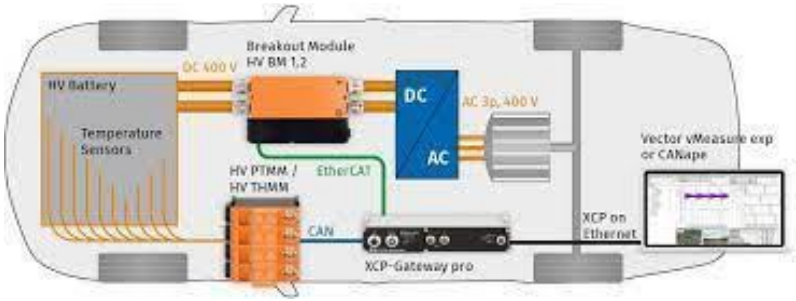
TSI - basic electrical education



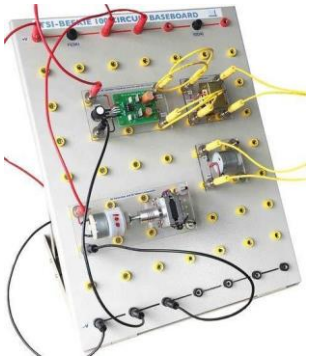
- TSI Hybrid Vehicle Training Module



- Theoretical material for education in EV both theoretically and practically.



- Materials for the construction of a circuit for hybrid/electric vehicles



- Electric vehicles for training and measurements, easy to see all the different components of the system.

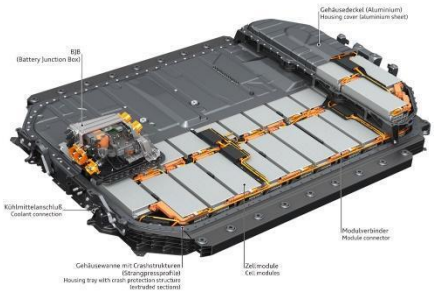
- TSI Training materials for handling disconnection and proper and safe procedure. Troubleshooting training board, box with built-in errors.

- Electric vehicles for training and diagnosis

- Hybrid vehicles for practical training

- Basic equipment for measuring, for example, insulation, voltage, insulated tools for work in the high voltage system.

- Components of EV systems such as high voltage battery, electric AC compressor, powertrain, electric motor.



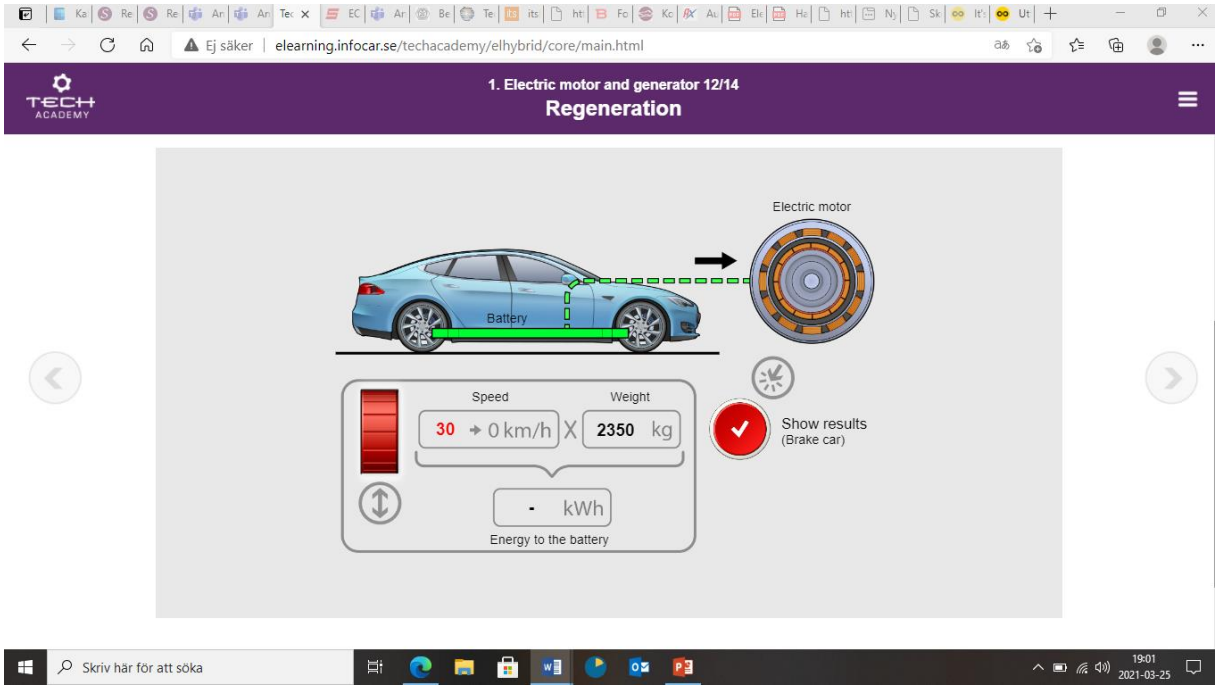
Examples of requests regarding electric-powered trucks and construction equipment[6]

- A truck with hybrid drive, electric/diesel,
- An excavator Volvo EC18 Electric for example from Swecon,
- A loader Volvo L20 Electric for example from Swecon,
- A truck with hybrid drive, for example from Volvo or Scania.

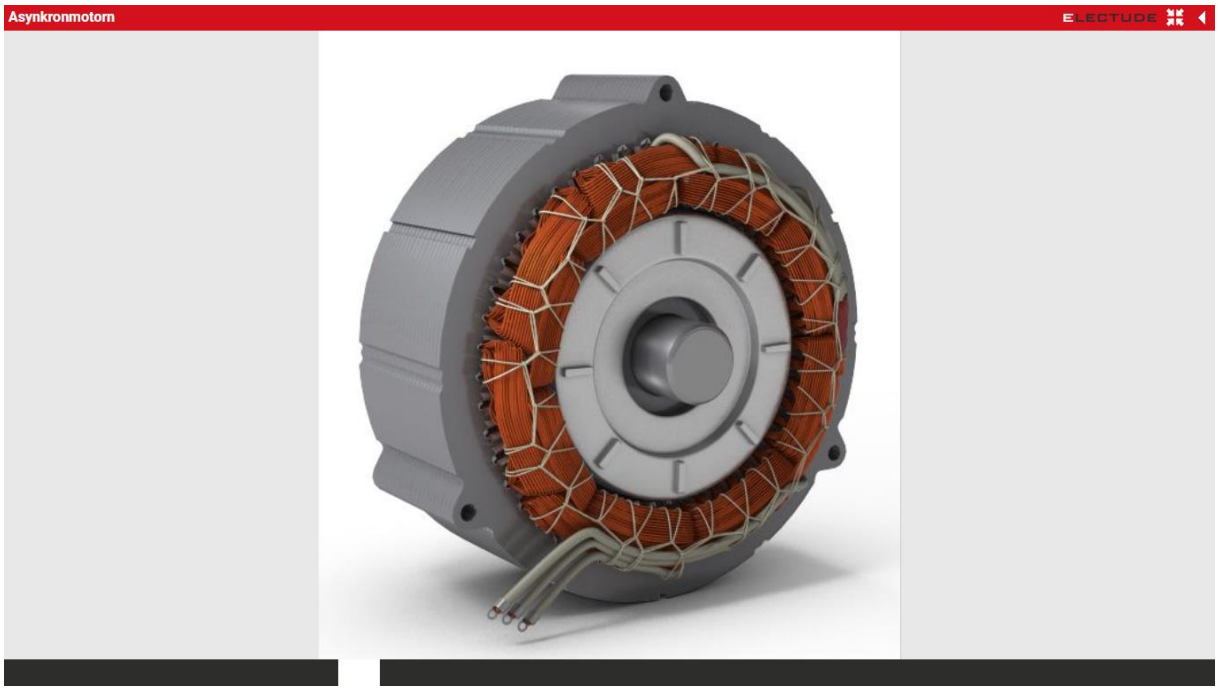
[6] Keijo Sipinen, teacher in vehicle technology, specializing in electric power trucks and construction machines, Nyköpings gymnasium, Sweden

Examples of requests regarding training materials for e-vehicles

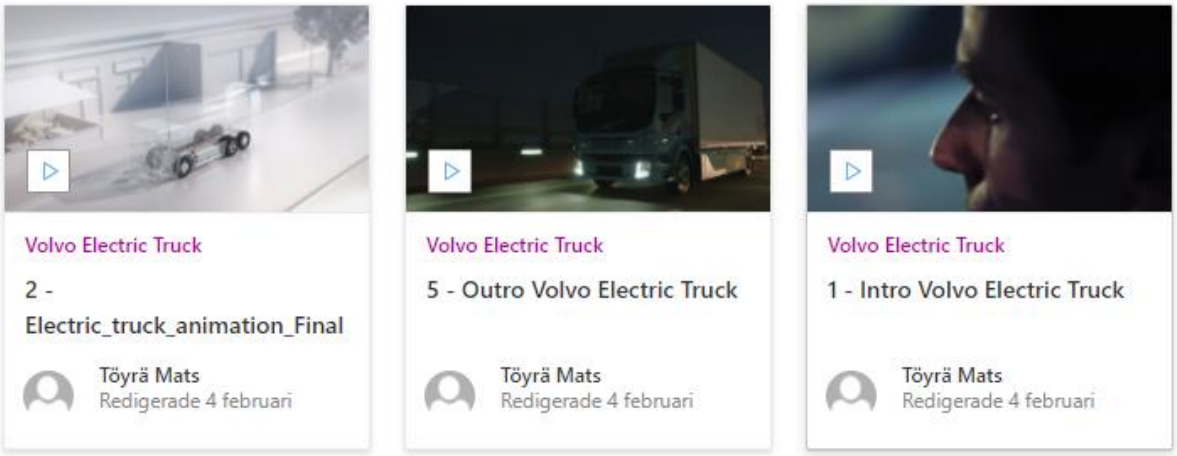
- Tech academy to show our learners information about EV

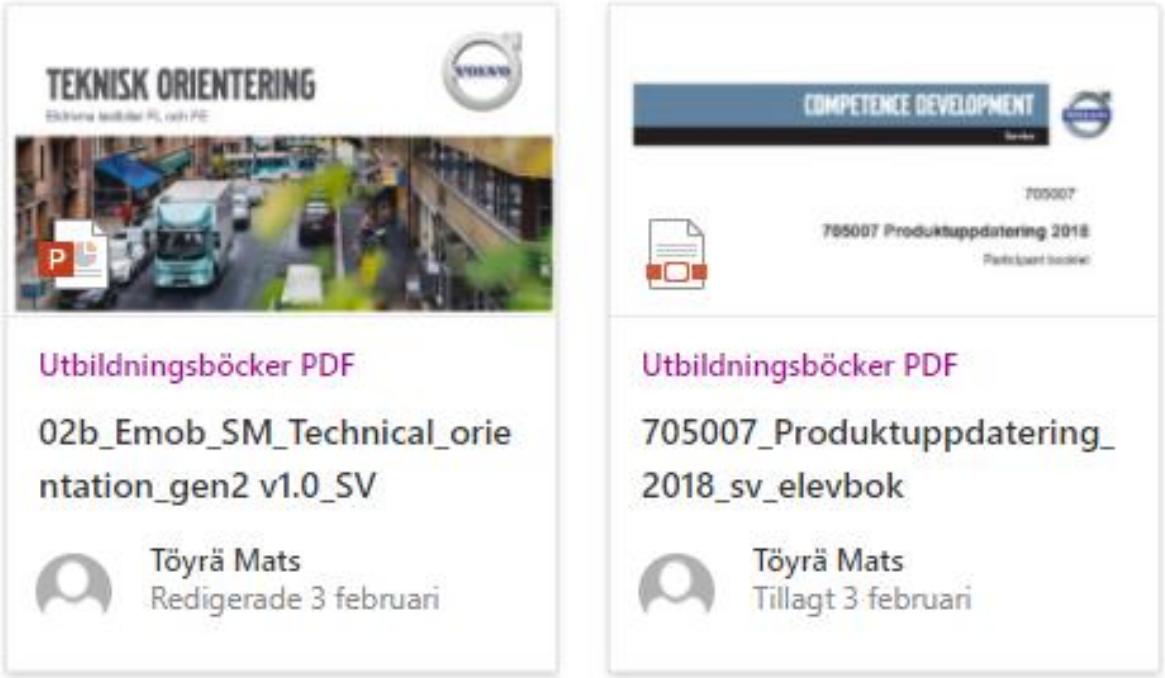


- Electude, A program for learners second and third years in Sweden



- Gleerups, a digital theory material for first-year vehicle learners in Sweden
- Material from Volvo describing the EV systems for different types of Volvo models and materials from Mercedes about Electric Vehicles





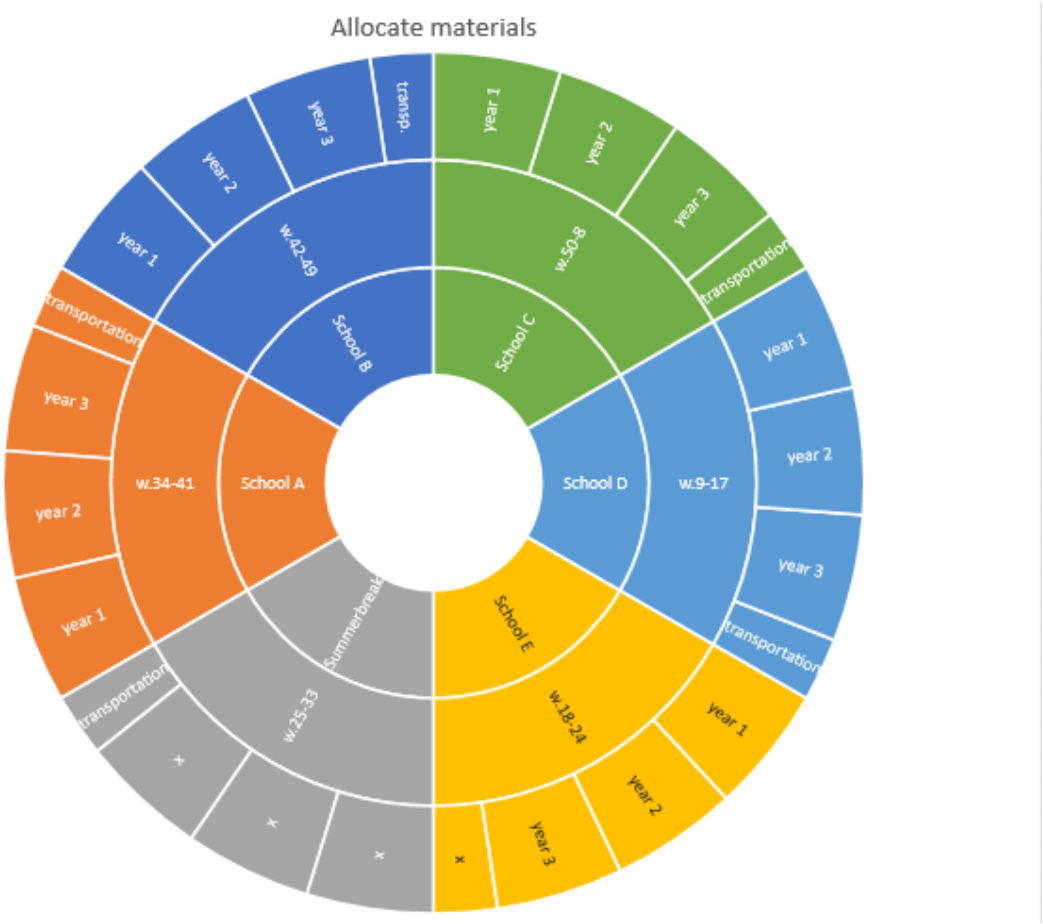
Proposals for teaching materials and equipment that offer collaboration opportunities between vehicle training, companies, and trade associations by Bäckadalsgymnasiet, Uppsala Yrkesgymnasium Ekeby, Erikslundsgymnasiet and Nyköpings gymnasium in Sweden

These proposals have been developed by participating vehicle teachers at Bäckadalsgymnasiet, Uppsala Yrkesgymnasium Ekeby, Erikslundsgymnasiet and Nyköpings gymnasium in Sweden.

Education cooperation has great development potential and deserves clearer goals, funds, organisation, and evaluation. Good educational and training cooperation can bring benefits to everyone involved. Collaboration enriches vehicle learners' learning and facilitates the transition to work. Teamwork can also benefit the vocational program for vehicle technicians, by making new contacts contribute to the high quality of vehicle training. Cooperation also provides possibilities for increased knowledge for teachers and the opportunity for in-depth learning by knowledge sharing. Alliances can also take place at staff level e.g., that teachers teach at a school other than their own in a specific area.

A proposal for a sharing system between schools so that each individual school does not have to acquire all the materials and equipment themselves[7].

Suggestions on how teaching and training materials and equipment for e-vehicle teaching can move between schools:



School A-E changes every year, no school has the same letter year after year

All schools get eight weeks with adjustment for Christmas and summer holidays (as well as a week in the spring for school D), in the schedule you see an intro for year 1, year 2 and year3,

[7] Draft by Max Michael, teacher in vehicle technology, specialising in electric passenger cars, Uppsala Yrkesgymnasium Ekeby, Sweden.

it is certainly not that you can evenly divide between grades, but to show that all grades are included.

Transport means that it is the school with the material is responsible for contacting the receiving school and thus deciding how/when/where material is handed over.

At four schools, the schedule would look as follows:

A sharing system is costly effective for education providers in the motor industries where technology development is ongoing[8].

Local programme councils between the school and local vehicle repair shops, which work, are a fantastic asset, in terms of materials. For example, companies can offer helmets with adapted teaching materials, which schools can use in their teaching. Practical teaching in working with tension-set high-voltage systems. Learners can, in connection with the

[8] Marcus Ölin, Industry developer Motorbranschcollege

demonstration of an HVE from a collaboration company, participate in eye-turning work under supervision.

There are development opportunities that require school leadership coordination across municipal boundaries. In Dalarna County, certain cooperation between schools in Borlänge and Falun can be established if there is permission from school management, then collaboration is scheduled. Regionally, a network of vehicle teachers has also been created which can be developed further[9].

Motorbranschcollege (MBC) is a Swedish quality system for automotive technical vocational education that targets specially selected upper secondary schools. MBC collaborates with general agents on equipment and training for teachers and learners. MBC establishes local and regional cooperation between vehicle trainers and engineering companies with internships and sponsoring workplaces for learners at workshops with electric car service. Today, general agents and brand workshops provide a large part of the training required for service and safety when it comes to electric cars, partly because routines and certification are specific to each brand and model. Although a general education based on Industry Practices safety and responsibility issues in relation to the Swedish National Agency for Education's syllabuses, aimed at teachers and responsible principals/politicians is desirable.

A common portal is necessary where schools can share their theoretical material and their didactic approach in the education of electric and hybrid vehicles. This can facilitate vehicle education and support quality education in the subject area.

Planning the various educational elements schematically enables a sharing system of materials between nearby schools as well.

Continuing education for automotive technical teachers

Changed curricula to meet this change also govern the teacher's teaching tasks to stand up to the unproven learning goals and requirements for knowledge to take on the new technology.

[9] Pär Winther, teacher in vehicle technology, specializing in electric passenger cars, Erikslundsgymnasiet, Sweden

The technology shift is rapid and accelerated by the automotive industry's transformation and climate needs.

The interest in continuing education is significant mainly for electricity/diagnosis and high voltage. A survey sent to vehicle teachers in Sweden and industry trainers indicated that both the industry and the automotive engineering teachers have a need for continuing education in specified areas[10] .

Our research[11] shows that vehicle teachers have a significant interest for continuing education mainly in electrical/diagnosis and high voltage, such as:

- General safety procedures for repair of electric vehicles
- Electrical engineering, measurement methods, measuring instruments and component knowledge,
- Electric powertrain,
- Battery technology, electrical machines, power electronics, hybrid systems.

It has also emerged in dialogue with vehicle teachers and industry educators that automotive engineering teachers at upper secondary level need pedagogical and didactic aspects of education, with a focus on e-vehicles.

Norway

There are currently no national regulations related to work on electric vehicles. This applies to mechanics, teachers, and learners alike.

The large car companies have their own courses for their employees, where it is the car factories that decide what requirements there should be for mechanics. These requirements are different from car brand to car brand and have different levels. For workshops that are

[10] Stefan Lust, industry trainer e-vehicles, Promeister AB, March 2021

[11] Questionnaire sent to vehicle teachers, responder 35.

not dealers of a car brand, courses and expertise will be difficult to attend, and there are no general requirements. This also applies to teachers.

In education, it is then the competence objectives in the curriculum that indicate a minimum competence for teachers. Teachers must acquire competence well enough to teach the learners the various competence objectives. As a school, Byåsen videregående skole are fortunate to have good partners in the car companies, where we get an opportunity to participate in some of their courses for electric cars.

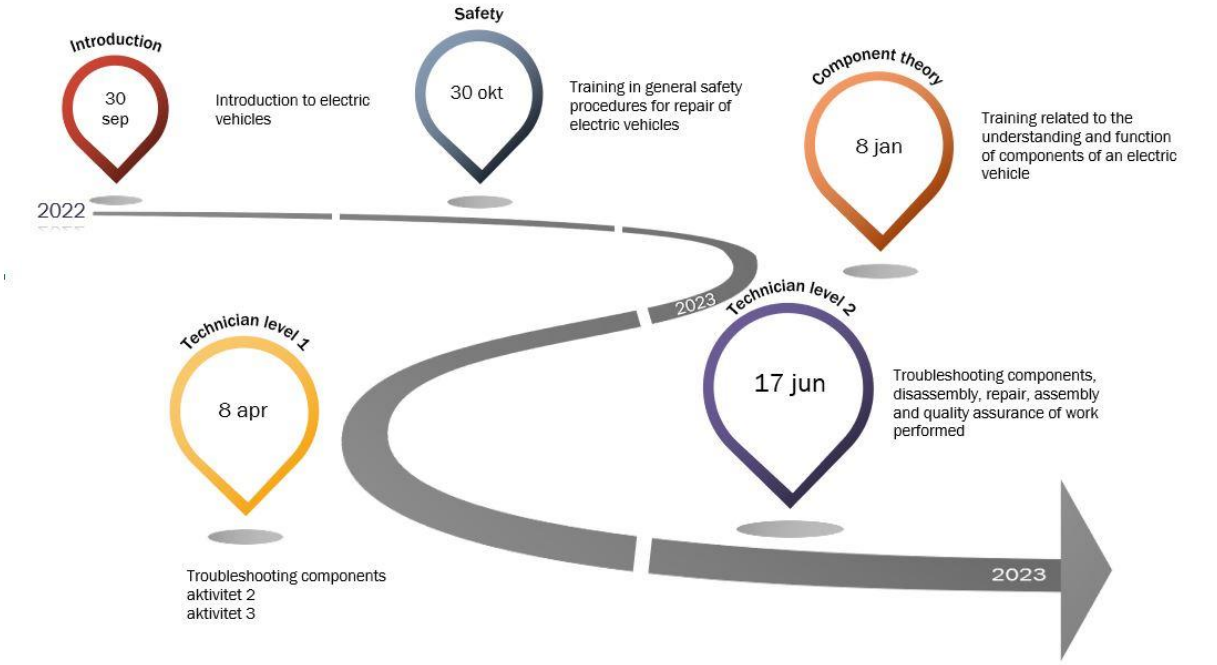
For Norway, there should be standardised requirements for work on electric vehicles, and through this we could ensure that such work is carried out by personnel with sufficient expertise.

Through the networks of schools and the automotive industry, there is a desire to develop specific requirements for what a mechanic in a company must have as a competence. This will then also apply to teachers who provide instruction, and through this generate the conditions for knowledgeable teaching of learners.

For Norway, there has just been an update of curricula, and schools and the automotive industry worked to get requirements for electric car training into the plans. We only partially succeeded in this. The curricula are only a minimum requirement for training, and as a school Byåsen videregående skole can therefore set larger internal requirements. What is unfortunate, then, is that the different schools provide different training based on the varying competencies of its teachers. The new curriculum opens for a new method of teaching where learners will learn through exploratory learning, and teachers will change their teaching from knowledge dissemination to facilitating learners to acquire knowledge in a research way. In the new curriculum, great emphasis is placed on the concept of competence, where it is defined as competence is to use knowledge in known and unknown situations.

The new curricula include only general goals for the learners and nothing about the teacher, and therefore not so many concrete requirements for teachers' competence in electric-powered vehicles (High Voltage Systems).

The teachers at Byåsen upper secondary school will in 2022 start training in the use of our technical teaching equipment. This will be carried out by the equipment supplier, and internal training will be carried out.



Picture: Training plan for employed vehicle teachers at Byåsen upper secondary school

In the future, Byåsen upper secondary school wants to organise a nationwide technical education for electric car mechanics, then through our technical vocational school and our course and resource centre. We have also started to develop educational films and use QR-codes for accessing the films.

This will be available both to teachers and to mechanics employed in private companies. Byåsen upper secondary school want to build their educational resources according to the model that is suggested for Sweden, see page 27.

In cooperation with other schools, internal courses will be arranged at Byåsen upper secondary school, because our training equipment is too big to transport between the schools. The school has offered our partners to use our learning facilities for both their own courses, as well as in the future to be able to participate in our courses in the future.

Estonia

Undertaken interviews with teachers[12] revealed that competencies vary widely. There were teachers who revealed that they could not teach anything in this area. Many found their knowledge to be purely theoretical, while some felt at home in the field. Many complained about the teaching materials and especially about the shortcomings of practical training.

It was mentioned that with the rapid development of this technology, companies, which often have the necessary knowledge, will have an advantage. However, it was also revealed that different schools have different opportunities and expertise in this area. Thus, schools with the necessary teaching stands and materials could make short training days for teachers from other schools interested in the subject. Of course, this does not solve the problem of practical learning in their home school. But if there are no teaching aids in some schools, but this would be one way to raise the level of theory education in those schools.

It was also revealed that teachers have a problem acknowledging that they do not work in this field and therefore do not want or dare not to develop. On the other hand, people who could educate others in this field do not dare to do so because they think that the knowledge, they offer is too low and they are not developing anyone.

Together, we found that the best way to educate teachers on training days or in real e-cars is basically the same method as for learners. After acquiring the basic knowledge, do the next training for higher masters, etc. It is often assumed that teachers' knowledge is always much higher than that of the learners, but this may not always be the case for 'new technology', in

[12] Interviews conducted by Margus Kivi, teacher of Automotive Engineering, Specialisation in Electric Passenger Cars, Kuressaare Ameticool, Estonia, March 2022

which case it is non-existent or very easy to teach higher competence without acquiring basic knowledge.

When researching the minimum level of knowledge required by companies, the answer was that students generally have a general knowledge of electric and hybrid cars, and from there they can train them in the required direction. Of course, it must also be mentioned that, at present, the share of electric and hybrid cars is not high at all and, as a result, they cannot accurately predict the number of competent staff they will need in the future.

Sweden

During our inventory of teacher competence to achieve these goals, these points need to be prioritised:

•Knowledge of what "INDUSTRY STANDARD - safe handling of high-voltage systems in electric vehicles" versus the Work Environment Act says regarding the management of high-voltage systems, a good way is to attend a YH training that deals the role of "electrical safety officer" to get a handle on the different responsibilities when it comes to working on high-voltage vehicles.

- Who has responsibility for the work environment? Are you aware of the responsibility you take if you accept a delegation of this?
- What structure and routines do you have for safety work at the school?

• Training for vocational teachers on how to troubleshoot different components of the "power electronics" (inverter/converter), battery balancing, and powertrain (synchronous /asynchronous motors). An understanding of the function is important to be able to find didactic entrances to the teaching of learners.

• Knowledge of the content of syllabuses within "high-voltage vehicles" published by the National Agency for Education, what does it mean that the learners should have "made a high-voltage vehicle" de-energized? How does the school approach the central content of the

courses, do you have the knowledge, materials, and teacher resources to carry out training elements in a safe way?

• Needs for educational and didactic aspects of education, with a focus on e-vehicles. How can the learners repeat moments without the teacher being physically present? Erasmus project Erasmus+ New digital teaching and training practices in e-vehicle education, Erasmus+ 2020-1-SE01-KA226-VET-092422 points to new didactical and pedagogical approaches to digital teaching and training practices in e-vehicle education. Where it is possible to create video modules that the student can work independently for their further learning after the introduction of teachers, e.g., clear reconciliations at risk moments are added to the films.

All schools/programs may not have the resources or knowledge needed, one way to increase the opportunities to achieve the goals is to collaborate in different ways. VET providers can collaborate around the physical material at the local or regional level and can also expand the collaboration to include the knowledge that each teacher has or acquires by letting the teacher go to collaborative schools and there carry out training with the learners at that school. In this way, each teacher gets to carry out their part of a course more times a year, which means a larger routine around the didactics needed for the different parts. Examples of on-line resources for education and training for VET teacher in high voltage vehicle can be found in the annex as well. *Collaboration gives strength both in content and to the professional role of Vocational teacher.* [13]

What can we share transnationally?

It is much easier to share theoretical materials internationally than physical studies stand. Practical spreadsheets developed by schools can be shared transnationally. All this helps to raise the school level in different countries while harmonising the level of competence. Teaching materials can be easily shared between schools and countries, as there is good software, and there are tools for translating text into the different languages. Sorted by safety

[13] Jan Börstell, teacher in vehicle technology, specialising in electric passenger cars, Bäckadalsgymnasiet, Sweden.

management and individual e-vehicle products and models. VR and AR technology in teaching. Learners who have challenges with reading and writing can still become particularly good mechanics[14]. It is important that multi-modal teaching programs with good movies and animations allow learners to conduct basic safety training in a safe environment before being carried out on vehicles. This type of teaching also makes it easy with group training for the learners even if we do not have sufficient teaching equipment and electric cars in the school workshop.

It is also important to establish a work group that can share practice, to develop the organisations and the teaching both locally, nationally, and transnationally. Participating in Erasmus+ project presents a lot of new knowledge and promotes teacher competence. We share study materials across borders and learning simulators. Make new contacts with specialists in the field of electric and hybrid cars, from whom you can always ask for help. Distributing various teaching materials to other teachers and take part in the learning opportunities offered by teachers' networks in the EU supported by Erasmus+. Through this we can developed our own ideas on how to make learning better and more efficient[15].

The network that we are building now will be of great help to us in the future for us in the EU.[16]

[14] Statement by Roger Rosmo, leader for technology and industrial subjects, Byåsen videregående skole

[15] Conclusion and recommendation by Margus Kivi, Teacher of Automotive Engineering, Specialising in Electric Passenger Cars, Kuressaare Ameticool, Estonia

[16] Pär Winther, teacher in vehicle technology, specializing in electric passenger cars, Erikslundsgymnasiet, Sweden

Recommendations

The report has the following proposal of education materials and equipment needed to conduct qualitative teaching and training in high-powered vehicles. The proposals are a summary of a completed needs inventory and suggestion below are developed by Max Michael[17] and agreed by participating vehicle teachers in Norway, Estonia, and Sweden, as basic needs.

1. Basic modules for electrical engineering, exercise benches/stations for working with electrical engineering.
2. Theoretical material for training in electric vehicles with both a theoretical focus as well as in a practical manner.
3. Training materials for high voltage e.g., powering down TSI boards.
4. Electric vehicles that can be used when teaching in accessible way, such as smaller vehicles where the systems are clearly visible.
5. Electric vehicles with associated diagnostic equipment to be able to see functions and perform a diagnose on the High Voltage part.
6. Basic equipment for measuring voltage, insulation measurement, blocking electric vehicles and insulated tools for high volts.
7. Components to have in the teaching such as high-voltage battery, AC compressor, electric motor, generator, powertrain and charging station.

Proposal of continuing education and training for automotive technical teachers

- General safety procedures for repair of electric vehicles,
- Electrical engineering, measurement methods, measuring instruments and component knowledge, Electric powertrain,
- Battery technology, electrical machines, power electronics, hybrid systems,
- Pedagogic and didactic aspects of education and training, with a focus on e-vehicles.

[17] Max Michael, teacher in vehicle technology, specialising in electric passenger cars, Uppsala Yrkesgymnasium Ekeby, and representative in Motor Industry Council at the Swedish National Agency for Education.

Proposals for teaching materials and equipment that offer collaboration opportunities between vehicle training, companies, and trade associations

A shared experience-based point of view so that there can be benefits to coordinating the education of teachers locally, regionally, nationally and across countries. The challenges are the same, the cars are the same, the level of competence should be the same, but the path to competence can be different as the equipment in the schools is different. VET providers and the industry can help by offering partners the use of learning facilities and continuing educational courses and training for VET vehicle teachers with institutional strategy and methods of organized collaboration. Educational material for qualitative teaching and training in high-powered vehicles can also be exchanged on an international basis.

Recommendation:

- Establish a contractual sharing system of teaching and training equipment, materials, and training courses for teachers with partners who share a common interest and have incentives to increase a quality learning outcome.
- Work actively in networks for benchmarking and to expand sustainable collaborations.
- Use Erasmus+ funding for the upskilling of automotive teachers and to share know how between VET providers on a European and global basis.

Appendix

The Norwegian car industry has created a textbook that is an app: the Bilfag app. With it, automotive learners, apprentices, schools, companies, or other car enthusiasts get a modern and 100 percent professionally up-to-date tool in several languages including English. It includes Animation of DC-engine, Animation of AC-engine (1-fase and 3-fase), Illustration of Components in the electric engine, Animation of Syncron-engine, Animation of asyncron engine, Animation of inverter, Animation of battery types, Animation of regeneration function, Animation of inverter, chapter about electrical safety etc. Download it for free on the app store Link: Bilfag - El og hybrid

Global education and training material for e-cars suggested by Tesla[18]

- find some nice videos there: https://www.youtube.com/tesla
- Here are a few other really good YouTube channels related to Tesla and electric cars in general: https://www.youtube.com/c/Ingineerix/videos (really recommend the video about CAN bus for example, best one I have seen so far. All his videos are great.).
  https://www.youtube.com/c/WeberAuto (this is a car mechanic school in the US that have really good videos on EVs and Hybrids. A bit long, but very in-depth).
  https://www.youtube.com/c/MunroLive/videos (Munro is an Engineering company that tears down cars to the smallest possible part and sells the data they collect to the car manufacturers. Very interesting videos).
  https://www.youtube.com/c/SuperfastMatt (X-engineer from Tesla that builds cool things. Not so school related, but funny and interesting).
- This is the Tesla Page for First Responders (fire department for example). There are High Voltage safety related information here that you might find interesting.
  https://www.tesla.com/firstresponders

[18] By Karl-Kristian Nyborg, chief technician, Tesla Trondheim, during an interview made by the project team, Dec 2021.

- Tesla Impact report. Here you will find a lot of info about the water consumption to produce batteries, CO2 emissions, where the materials are coming from (mining)++ https://www.tesla.com/ns_videos/2020-tesla-impact-report.pdf
- https://www.tesla.com/ If you use the menu here you can find a lot of things. Information about charging for example. Technical support information. Solar panels, and much more.

Tips for vehicle teachers is to look for self-study material in measures to maintain a high level of safety for all those involved in the work of electrified vehicles[19].

[19] E.g in Sweden The Industry standard safe handling of high-voltage systems in electric vehicles only available in Swedish Branschstandard- säker hantering av högvoltssystem i elfordon