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Exploring how automated technology and advanced driver-assistance systems (ADAS) are taught in the Norwegian driver-training industry. A qualitative study.

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Car technology is rapidly evolving, with advanced driver-assistance technology changing the role of the driver. This should be reflected in the teaching of learner drivers. However, little pedagogical research is available in this field for the driving-instructor industry to draw on, and little is known about how this is taught within the driving-instructor industry. Therefore, we explored the research question, How does the Norwegian driver-training industry teach advanced driver-assisted technology to learner drivers? We interviewed 10 driving instructors from different parts of Norway and used thematic analysis to analyse the data. We found that teaching does not correspond with technological developments. The driving instructors do not define learning outcomes related to new technology, and the national curriculum is not well suited for the developments in automated technology. There is a need for knowledge within the driving-instructor industry concerning developing pedagogical processes suitable for variations in technological standards in cars on the roads.

Keywords: driver training, ADAS, automated technology, learner driver, teach, driver-assistance technology, driver behaviour

1. Introduction

Car technology is evolving fast. Every year, new technological solutions are presented for drivers, and the technology is becoming increasingly complex and automated. It also differs between car manufacturers, resulting in a lack of standardization. The driver-training industry must consider the rapid pace of development in their training and pedagogical teaching (Sætren et al. 2018). However, how the Norwegian driver-training industry use new technology, present it for learner drivers, and teach it for desired learning outcomes have not been explored. Consequently, the research question was, How does the Norwegian driver-training industry teach advanced driver-assisted technology to learner drivers?

Next, we present literature on levels of automation, recent literature on how automated technology should be taught to learner drivers, and an overview of the Norwegian learner-driver curriculum.

1.1. Levels of automation

Several taxonomies have attempted to capture the essence of the development of advanced technology in cars, and the most common seems to be the levels of automation set out by the Society of Automotive Engineers (SAE; 2021). This approach is based on six levels of automation ranging from no automation (Level 0) to full automation (Level 5). Level 0 is no driving automation, Level 1 is driver assistance, Level 2 is partial driver assistance, Level 3 is conditional driving, Level 4 is high driving assistance, and Level 5 is full driving automation. In SAE Levels 0 to 3, the human driver is responsible for driving, and in SAE Levels 4 to 5, the car takes on this responsibility.

The SAE taxonomy concerns the role and tasks of the technology and the technological perspective, and how it takes over human operator tasks. However, it does not address how human tasks, understanding, and behaviour change from level to level. It further does not address the

responsibility of a human operator for each level, and thus how it should be taught.

1.2. Teaching advanced driver-assistance technology to learner drivers

Over the past three to four years, there has been a slight increase in scientific literature on how to deal with the new technological solutions in the driver-training industry (Forster et al. 2019; Lubkowski et al 2021; Sætren et al. 2018). In addition, Manser et al. (2019), in a report on driver-training guidelines for automated vehicle technology in the United States, identified five levels of educational requirements for skills and knowledge drivers should be trained on when using advanced driver-assistance systems (ADAS):

1. Purpose of using ADAS, including risks and benefits
2. Understanding levels of ADAS, including capabilities and driver's level of responsibility
3. Transition between ADAS and manual mode and handling critical situations, including system malfunctions
4. Familiarity with system components and placement, including sensor and radar camera
5. Understanding the limitations of ADAS, including adaptive cruise control, lane-keeping assistance systems, and emergency brake assist)

1.3. Driver training in Norway

The driver training in Norway is based on a stepwise system from level 1 to 4. The driver training is based on the GDE matrix (Peräaho, M.Kaskinen, 1996; Peräaho, Keskinen &Hatakka, 2003). There is a level assessment lesson between each level, where the learner driver together with the driver instructor makes an assessment of the skill level of the learner driver. In these assessment lessons they decide whether the learner driver has obtained sufficient skills to start the next level of training.

In Norway, you can start such training at the age of 16 years. The training can be completed at the age of 18 with a practical driving test. The training is comprehensive with both theoretical and practical lessons. The Norwegian driver training separates mandatory and non-mandatory training. The traffic school is often small units with few employees. The Norwegian Public Roads Administration has its own quality assurance system which is to ensure that traffic schools work within the framework of quality when it comes to educational activities.

Technology in the Norwegian driver-training Class B curriculum

In the Norwegian Class B driver-training curriculum, technology is mentioned in a few places (NPRA 2017). This curriculum is based on the stepwise training progress for learner drivers in Norway. Thus, it is divided into four levels: Level 1 covers theoretical knowledge, Level 2 covers basic vehicle-handling skills, Level 3 covers tactical skills, and Level 4 covers strategic skills.

In the Norwegian driver-training curriculum, the term *driver assistance* is used. This term covers all technological equipment from SAE Levels 1 to 5 (SAE 2021). Teaching technology and driver assistance are mentioned in Level 1 of the curriculum when discussing the theoretical aspects of driving in the dark and the learner drivers are introduced to the correct use of light. New lighting technology in the form of adaptive lighting is an important topic at this stage, and visibility and appropriate lighting use are described. Furthermore, topics such as understanding the meaning of automation and basic actions and action patterns are discussed. Technological solutions that take over parts of the driving process are included in the course.

In Level 2, driver support is mentioned in several places. The training regulations set out that the learner driver (1) must account for the car's structure regarding safety and the environment, (2) account for human capacity and traffic requirements, and (3) get ready for driving, and (4) the learner driver must review safety controls. Through the Level 3 training, the learner driver must master driving under various traffic conditions. This level includes safety courses on a training track, during which driver-support technology is a key theme. These safety courses create the basis for Level 4, the final training stage.

During Level 4, the learner driver must complete a compulsory safety course, which focuses on the learner driver's understanding of risk and the traffic system. Concepts such as driving ability, risk, possible risk factors, and

appropriate driving style are linked both directly and indirectly to driver-support systems. During the practical test at the Norwegian Public Roads Administration (NRPA), the learner driver has the opportunity to use all types of driver-support systems in addition to full parking assistance.

2. Method

We chose a qualitative design for this study, conducting semistructured individual interviews and using thematic analysis to analyse the transcribed interviews. This study is the beginning of a larger project exploring pedagogy and teaching of the use of ADAS for learner drivers.

2.1. The researchers

The researchers are experienced in driver training and human–technology interaction and learning. One is an associate professor who specializes in ADAS technology and teaching and has more than 10 years' experience as a driving instructor. One holds a PhD in human–automated technology interaction and now specializes in the interaction between automated and cognitive technology, and end users. She has further worked for many years within research on driver training and technology, and learning through simulation.

2.2. Literature review

To identify up-to-date literature on the topic of teaching ADAS technology, we conducted a literature review. We used the Oria and Google Scholar search engines and set the timeframe to the past five years to yield the most recent literature and because little was written on this topic before that (Sætren et al. 2018). The search terms were 'teaching automation', 'driver behaviour', 'driver instructor and automated technology', 'driver training and automated technology', and 'advanced driver-assistance systems'. Most articles concerned driver–technology interaction, and only a few concerned the teaching and pedagogical view.

2.3. The participants

The informants for this study were driving instructors. For a varied sample, we invited driving instructors from different parts of Norway with varying experience in teaching learner drivers. One woman and nine men agreed to participate, and they all came from different driving schools. To become an authorized driving instructor in Norway, a two-year university education is a minimum requirement.

2.4. The interviews

We conducted 10 individual semistructured interviews (Kvale 1996) in November and December 2021. Due to coronavirus restrictions, the interviews took place digitally via Zoom Meetings or Microsoft Teams or telephonically. All interviews lasted 45–60 minutes and were transcribed for analysis. All interviews were conducted with one or two interviewers present.

2.4.1. The interview guide

Before the interviews, we developed an interview guide that consisted of themes and questions regarding how driving instructors implemented technology in their teaching. Examples of questions include the following: 'Can you describe your background?' 'What do you teach?' 'Can you describe the car you use, including the onboard technology you use for teaching?' 'Where in the curriculum did you find technological issues?' 'What learning outcome is your objective for your learner drivers when you teach technology in cars?'

2.5. Analysis

We used thematic analysis (Braun and Clarke 2006), as this method provides a flexible analytical approach that is inductive and theory neutral. Furthermore, we used QSR NVivo 12 software to organize the data. We prioritized codes related to which technology was taught and how each technology was reflected upon according to learning processes and learning outcomes.

2.6. Validity

There are several approaches to quality in qualitative research (e.g., Kvale 1996; Yardley 2000). We followed Yardley's characteristics of validity: (1) sensitivity to context, (2) commitment and rigour, (3) transparency and coherence, and (4) impact and importance.

2.7. Ethics

All informants provided written informed consent by signing an agreement to participate. Sikt (formerly the Norwegian Centre for Research Data, or NSD) approved the project as being in accordance with GDPR principles.

3. Results

Table 1. Themes related to automated technology and advanced driver-assistance systems (ADAS) taught in the Norwegian driver-training industry

Category	Illustrative explanation
1 Level of training and learning	Training and learning do not align with technological developments.
2 Learning outcomes	The driving instructor does not define the learning outcomes besides the learner driver's need to gain experience.
3 Potential and limitations of the curriculum	The curriculum is vague on specific formulations that deal with technology. The concept of driver-support systems has a broad scope for interpretation.
4 Need for knowledge	The driving instructor recognizes a great need for new knowledge about technology but is uncertain about how to update such knowledge.

3.1. Level of training and learning

Levels of training and learning do not align with technological developments, as the driving instructors were found to work in SAE Levels 0 and 1. Driver-support systems are specifically mentioned in several places in the curriculum; for example, in the compulsory safety course conducted on the practice range, the learner driver experiences such systems. The size of the area, driving pattern, capacity, and safety zones determine the speed and training moments to which the learner driver is exposed. The instructor is often limited to working with the anti-lock braking system (ABS), electronic stability program (ESP), and traction control. Few opportunities arise to work with systems such as adaptive cruise control, emergency brake assist, and lane assist system. When asked if the use of new technology is emphasized in the training courses, one informant replied, 'We work with stabilization programs and ABS brakes. There are very few who take advantage of the other opportunities that lie there.'

3.2. Learning outcomes

The driving instructors have different approaches to learning outcomes besides the learner driver's need to gain experience. The teaching has a narrow perspective in terms of experiencing instead of understanding and analysing. Due to a strong focus on ABS and ESP, some instructors feel that this topic is being over-addressed: 'I spend a lot of time on ABS and ESP, like everyone else does. This topic is treated more than necessary, really.'

The driving instructors operate within the same regulations and curriculum, but our analysis shows great variety in approaches to how to achieve the learner driver's learning outcomes. Some instructors have difficulty defining clear goals related to specific learning outcomes. One respondent stated, 'I guess they understand that, but I do not test the actual learning outcome, so I do not know. I'm not sure what benefit they really have.'

Some instructors do not want a special learning outcome when teaching basic driving skills (Levels 1 and 2 in the curriculum): 'I do not want them [the learner drivers] to have any learning benefits there and then when we go through the systems in Step 2, but I just want them to know that there is actually a system that they will use later in the training.' Some instructors try to create a connection between the lower and higher levels (3 and 4) in the curriculum. Some instructors choose to use adaptive cruise control early on in Level 3: 'They get to try adaptive cruise control in different situations. The learner driver experiences where the technology works well, but they also experience areas, for example, on very winding roads, where systems are perceived as understeered and the learner driver defines their own driving as better than the technology.'

3.3. Potential and limitations of the curriculum

The curriculum is vague on formulations that deal with technology. The concept of driver-support systems has a broad scope for interpretation. The driver-training regulations and curriculum govern the training. The practical driving test also has a guiding effect on which elements are addressed in the training. One respondent stated, 'The learner driver is with us for one reason only and that is to get a driver's license. We can have good intentions, but the driving test is the ultimate goal.' Another stated that 'technology is not something that is measured on the practical driving test'.

The curriculum (NPRA 2017) refers to learning about driver-support systems at all stages of the training, but the extent to which the topic is discussed is subject to interpretation. The degree of technology as a theme depends on time, the learner driver's interest, the instructor's interest, and the learning outcomes of the teaching.

3.4. Need for knowledge

The driving instructors recognize a need for more knowledge about new technology but seem uncertain about how they should update this knowledge. Several instructors find the new technological solutions challenging. Some define their own point of view as good insight, whereas others are unsure whether their own competency is sufficiently current. Many feel confident with their own car's technology but are uncertain about all the variants available on the market. Moreover, many instructors are looking for platforms on which they can find the necessary knowledge. One informant stated, 'I want more updates on the topic. The development is going faster and faster'.

4. Discussion

Since estimations of road incidents generally conclude that the reason for crashes is human error (Manser et al. 2019), there seems to be a search for solutions within developing technology to avoid driver error. However, it is well known that implementing new technological solutions does not remove human acts and the potential for human error; rather, it shifts it (Sætren and Laumann 2015; Wickens et al. 2004). Thus, learning how to drive with ADAS is important. Consequently, knowing how new technology is taught within the driver-training industry is important. This led to the formulation of our research question: How does the Norwegian driver-training industry teach advanced driver-assisted technology to learner drivers?

The analysis revealed four main categories:

1. The levels of training do not align with all the levels of advanced technology.
2. The driving instructors do not focus on the learner drivers' learning outcomes regarding advanced technology.
3. The national curriculum is vague regarding advanced technology.
4. There is a need for knowledge among driving instructors on new technology and teaching new technology.

4.1. Physical facilities

The training tracks in Norway are operated by the Norwegian Automobile Association. The financial model is based on public support and a fee payable by everyone who uses the facility. Financial incentives to develop large facilities that reflect an ordinary road system are lacking. Some tracks have an open driving pattern with intersections and roundabouts, but most are small and with defined exercises, such as braking straight ahead, braking in turns, and evasive manoeuvres. Speeds are thus low in relation to the speeds learner drivers otherwise practice outside the track. If driving instructors are to work with higher SAE levels, track facilities must be strengthened regarding marking and recreating a road environment in which normal speeds can be used. Our findings in Category 4 show that instructors want to work with lane assist, adaptive cruise control, and so forth but are left to work with simpler driver-support systems due to the limitations of physical teaching areas. The Norwegian Automobile Association's facilities have been the subject of major upgrades in recent years, but the facilities are still a limiting factor in the training.

Some instructors regularly use a wider range of driver-assistance technology, often in real-life traffic rather than courses. According to our findings in Category 1, a few use the available opportunities, but some are more proactive about allowing learner drivers to use the systems if this provides safety gains. Most instructors do not

address the topic of self-driving regarding letting the car operate with lane centring and adaptive cruise control at the same time. Clearer guidelines for making such use of technology mandatory could thus provide a better teaching framework.

Some informants also questioned the legal responsibility related to Category 4, as they felt there were no clear definitions when it came to driver liability in the event of an accident. Does the driver by definition have the control of the car that the law requires when they release the steering wheel and the technology controls the speed?

4.2. Learning outcomes

Instructors often referred to the taxonomy verbs for learning outcomes in optional and compulsory training (NPRA 2017). The curriculum has thematic and step goals that are often specifically defined. Regarding driver-support technology, the instructors stated that such specific learning goals are lacking. They referred to the curricular concept of 'the learner driver must experience driver-support technology' (NPRA 2017). This learning goal is regarded as somewhat vague, according to our findings in Category 3, and is open to subjective interpretation. This has led many instructors and schools to create their own curricula on the topic.

The individual learner driver's learning outcomes seem be defined according to how interested the instructors are in new technology or whether the learner driver requests learning on the topic. Our findings in Category 4 show that instructors feel that they spend too little time on what they view as an important topic. They feel that the time the syllabus has set aside or the individual learner driver wants to spend on the topic is limited. Thus, they hesitate to provide in-depth explanations of training topics that comprehensively define driver support. The individual learner drivers also were reported to be disinterested in spending much time on a topic that is not compulsory or needed for the test. Both the learner driver and instructor knowing knowledge and skills are not tested on a practical driving test reduces the motivation for both teaching and learning.

Individual driving instructors want learner drivers to be left with a wide range of skills and knowledge related to learning outcomes. Some instructors want the individual learner driver to learn basic driver skills. This means having the competence to manoeuvre a car at SAE Level 0 (SAE 2021). Others focus on the learner driver's ability to assess their own competence against the mechanical and technological requirements at Levels 1 and 2. Many of the driving instructors believed that the topic of technology and driver competence will become increasingly important as the technology is implemented in the vehicles the driving schools have at their disposal.

4.3. Pedagogical tools

The Norwegian curriculum for passenger cars affords the driving instructor great pedagogical freedom. The driving instructors are trained to use pedagogical tools based on the learner driver's standpoint. The instructors' room to manoeuvre, on the other hand, is limited by rules and regulations that form the basis for what is to be learned and when it is to be learned, such as the Driver Training Regulations (Lovdata 2021) and the curriculum (NPRA 2016). The regulations deal, in particular, with compulsory training and address content and the use of time. Compulsory training to a lesser extent defines the use of time.

Both compulsory and optional training are defined through process and product goals. Technology and driver-support systems are mentioned at all stages of the training. This holds both potential and limitations. Defining in Levels 1, 2, 3, and 4 what to learn and focus on has potential. Level 1 deals with, among other things, driving in the dark. Through theory and demonstrations, learner drivers assess the use of light in the dark.

According to our findings in Category 1, some instructors use manually controlled lights and even believe that the driver performs these actions better than the car's automatic systems. Other instructors allow learner drivers to consider whether to use manual or automatic systems. At Level 2, some instructors begin the training by describing and explaining which driver-support systems the car in question is equipped with. Other instructors choose to define this later in the training. At Level 3, some driving instructors focus on using driver-support systems such as adaptive cruise control and lane-assist systems. Some driving instructors believe that the traffic-regulations training takes up so much time that none is left to spend on advanced driver-support systems. This is also often based on parents' and

learner drivers' financial motivations (Sætren et al. 2020). During the Level 4 safety course on the road, the learner driver must drive with the least possible risk. Some driving instructors include technology as an important topic by allowing learner drivers to experience the systems and decide for themselves whether these systems provide more or less risk, according to the Category 1 findings. Others talked about current systems but had no plan for how to use them or in what context.

Informants also mentioned limitations related to the regulations and curriculum. Most driving instructors believe that regulations and the curriculum should more closely govern the training content. Hence, they believe that clearer learning goals would help motivate them for such learning, according to the Category 2 findings.

Some informants advocated mandatory training for driver-assistance systems. The car fleet for Norwegian driver schools is relatively new, and most of the driving school cars have driver-support systems up to SAE Level 2. According to our findings in Category 3, informants stated that the time has come to revise regulations and the curriculum so that they better align with technological development. Several driving instructors also mentioned the final practical driving test. The test is, in most instructors' opinions, governing the training. With a greater focus on driver-support systems in the practical test, this would also be important for the training. Both instructors and learner drivers know that driver-support technology is not included in the test; thus, it can govern the training before the practical test.

4.4. Technology and pedagogical focus

A Norwegian driving instructor completes a two-year education at university level (see e.g., Sætren et al. 2020). Some driving instructors educated in Sweden and Denmark also obtain a Norwegian qualification by completing additional courses. According to the Category 4 findings, many of the informants wanted a greater focus on technology through education. The learning outcome description of the driving instructor education (Nord University n.d.) defines clear goals when it comes to technology and driver-support systems. Despite this, there was a clear perception among the informants that their own levels of knowledge and skill were weak and outdated. They often relied on Google searches and ended up with weak sources. Such a form of knowledge acquisition can, in the worst case, lead to incorrect training. The informants stated that, to a certain extent, it was a topic discussed on a collegial level. Some instructors pursued such conversations, whereas others felt it was irrelevant for their own training.

Moreover, some driving schools were found to focus on driver-support systems. They offered various courses and professional talks on the topic but did not report basing the pedagogy on international research on the topic. Other driving schools did not have this focus. This reflects the level of resources the individual driving school wants to spend on something that is perceived as a pure expense and not viewed as related to relevant learning outcomes for the learner drivers. A problem many informants pointed out is the variety of systems in different cars. The same technology may have a different name depending on the car brand. The informants reported having good control over their own cars for teaching these technologies but seeing learner drivers driving other types of cars at home as problematic. The informants also had a perception that the examiners assessing the candidates for the practical driving test had as little knowledge as the instructors about driver-support systems. Informants believed that they faced a challenge in that they have different censor systems in different cars. Thus, the driving instructors requested courses and additional education to update their knowledge and skills.

4.5. Implications and further research

This research paves the way for changing driving-instructor education to include more on how new technology should be taught. It further provides information for politicians and the NPRA on guidelines and regulations that should be adjusted.

In future research, a more gender-balanced sample would be preferable to explore whether there are gender differences regarding this theme. In addition, exploring *how* new automated technology should be taught and *which*

technology the driver training should prioritize would be beneficial for the whole industry.

5. Conclusion

The driving-instructor industry is in the midst of great technological change. There is no formal way of updating instructors' knowledge; thus, there are large variations in teaching new technology based on instructors' own interest in keeping up to date with these technological developments. Considering the variations in the technological standards in cars on Norwegian roads, these variations must be reflected in the driver-training programme as well.

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