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16. Abstract

The Novice Teen Driver Education and Training Administrative Standards (NTDETAS) reflect current and recommended practice in driver education and are based on a solid foundation comprised of expert opinion, experience, and consensus, and backed by scientific evidence when available. The purpose of this white paper is to identify information gaps and key research questions related to standards and address them with recent evidence to enhance the veracity of what is included in the NTDETAS; if what has been included is comprehensive and backed by scientific integrity of the NTDETAS. The primary research questions/issues identified related to three broad categories: the value of blended learning, the use of deliberate practice, and the application of technological approaches to driver education. These research issues/questions were addressed in this work effort by a systematic review of the literature in the field of driver education, and the broader literature on education, in general. A critical issue pertaining to the discussion on blended learning, deliberate practice, and technological approaches to education is the upcoming generational transition from Gen Z to Gen Alpha (born 2010-2025). Gen Alpha teens are more oriented to digital learning and technology and will start taking driver education in the next few years. The learning methods and tools discussed in this white paper are relevant to the standards and to this transition.

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Introduction

The debate surrounding the effectiveness of driver education in reducing crashes and fatalities is longstanding and complex (Mayhew & Simpson, 1996). While some researchers argue that driver education plays a vital role in equipping novice drivers with essential knowledge and skills, others question its ability to directly affect road safety outcomes. Compton and Ellison-Potter (2008) highlighted the importance of driver education in imparting fundamental understanding of road rules, basic vehicle control, and safe driving practices. These are crucial elements that contribute to a driver's competence and awareness on the road. Researchers acknowledge that there are factors beyond the scope of driver education programs that influence driving behavior and outcomes, such as environmental conditions, individual attitudes, and risk-taking behaviors. The complexity of these issues makes it challenging to isolate the specific impact of driver education on overall road safety metrics like crashes and fatalities.

Considering these challenges, the development and adherence to standardized guidelines, such as the Novice Teen Driver Education and Training Administrative Standards (ANSTSE, 2023), become essential. These standards serve as a framework for driver education programs, ensuring consistency, quality, and align with best practices. By incorporating expert opinion, empirical evidence, and consensus from the literature, the NTDETAS strive to reflect the most effective approaches to driver education. The first NTDETAS were developed by a group of volunteer expert representatives in the driver education field, later to become known as the Association of National Stakeholders in Traffic Safety Education (ANSTSE). The first NTDETAS were released in 2009, with the second edition released in 2017, and the most current edition released in May 2023.

Continuously reviewing the NTDETAS is crucial for ensuring their relevance and effectiveness in the evolving landscape of driver education. Identifying research gaps and addressing unanswered questions related to these standards can enhance their veracity and alignment with best practices.

As such, it was timely to re-engage diverse subject matter experts from a variety of fields and State driver education administrators to critically review new research to identify necessary updates to further strengthen the NTDETAS.

The purposes of this white paper were to conduct a systemic literature review in driver education and the broader literature on education in general, and to critically evaluate various components of the NTDETAS. ANSTSE members and State driver education administrators identified three primary research questions for review related to three categories: the value of blended learning, the use of deliberate practice, and the application of technological approaches to driver education.

A critical issue pertaining to the discussion on blended learning, deliberate practice, and technological approaches to education is the upcoming generational transition from “Gen Z”

("Generation Z")[1] to "Gen Alpha" (born from 2010 to 2025). Gen Alpha teens will be more oriented to digital learning and technology and will start taking driver education in the next few years. The standards and driver education need to prepare for the influx of Gen Alpha teens. The learning methods and tools discussed in this white paper are relevant to the standards and to this transition.

Blended Learning

Blended learning combines face-to-face interactions (NTDETAS, traditional classroom) in a classroom with online or virtual learning. This method can either be synchronous with a live instructor using, for example, a video conferencing platform in real-time allowing for discussion and evaluation, or asynchronous, where students learn content on their own schedule, within a certain timeframe without a real-time instructor. The NTDETAS already incorporates a blended learning approach in the adoption of several standards, including:

- several delivery methods with minimum instructional hours, including classroom (45 hours), and behind-the-wheel (BTW) training (10 hours), as well as 10 additional hours using a variety of delivery modes, such as observation, behind-the-wheel, range, simulation, classroom/theory (e.g., traditional, online, virtual, hybrid), online independent student learning (e.g., hazard anticipation training); and virtual/augmented reality; and
- learning to be delivered by some combination of face-to-face, virtual, and online activities.

The NTDETAS have recognized online education as integral to the delivery of driver education to supplement face-to-face classroom activities. From this perspective, the NTDETAS has adopted blended learning, which is consistent with best practices in the education field, in general, and an optimal approach widely viewed in the literature as the wave of the future. The flexibility in the NTDETAS about the use of the delivery modes is also an attractive feature that lets State driver education administrators to tailor and refine programs offered throughout the State to meet unique needs and learning situations such as for people in more rural areas without easy access to a bricks and mortar location.

Benefits

A key question in continued support for driver education, especially in a blended learning environment, is the extent to which established safety and learning objectives are being met. In this regard, the literature in the field of driver education and education has generally produced evidence of the benefits for both driver education (i.e., reduced crashes demonstrated in recent studies (see Kirley et al., 2023), and especially for blended learning delivered in a variety of

[1] [Editor's Note: The age ranges for Gen Z and Gen Alpha are somewhat fluid and depend on whose definition is being used; there is no definitive or "official" age range. Some sources claim Gen Z refers to people born in 1996 and later, and some say 1997. Some end the range at 2012, some say 2010, some say "mid-2010s" and another says "the early 2010s." One source says a "Millennial" is someone born from 1980 to 1995, which creates a problem if one starts Gen Z in 1997: Who are the people born in 1996? This report defines Gen Alpha as being born in 2010 and later; this means the very oldest Gen Alpha people at the date this report is being published are 13 years old and a some maybe 14 years old if born in the first few months of 2010. It also means Gen Alphas won't start driving or taking driver education until about 2026 and after. See discussion and citations on page 17.]

educational settings (i.e., student/instructor satisfaction, better interactions, and, most importantly, improved student performance).

Variations in Design and Approaches

Blended learning has been described as a continuum ranging from fully face-to-face classroom to all online activities with many different varieties and tools included within this approach (Watson, 2008). To this end, "one size does not fit all" (Cleveland-Innes & Wilton, 2018, p. 18). In fact, there are wide variations in design approaches to blended learning and a myriad of blended learning models; in other words, there are no shortages of models that can be applied to design and tailor a potentially effective blended learning course. As such, the NTDETAS and the subject matter experts that developed and updated it have a solid foundation for adopting a blended learning approach and ensuring there is flexibility in the design of the blend.

Time Allocations

Given the varied design of blended learning it is not surprising there is no consensus about the time split between face-to-face education and online activities. The blended learning literature generally supports the approach adopted in the NTDETAS regarding the allocation of time in the classroom (e.g., the 45-hour minimum classroom requirement is flexible, can be delivered face-to-face, online, virtually, or blended). While a somewhat subjective approach, the allocation of time in classroom (45-hour minimum) emerged from the opinions, experiences, and understanding of content, teaching strategies and student needs among subject matter experts.

Class Size

Class size is as critical an issue for blended learning as it has been for decades regarding face-to-face classrooms and, more recently, in online only courses. The issue of class size in a traditional face-to-face classroom, however, has been contentious, primarily due to concerns about institutional costs, teacher overload and burnout, as well as in achieving student interactions and academic success. The literature generally suggested the optimal class size for blended learning is a small class of 20 to 30 students, which is consistent with the NTDETAS requirement for driver education courses to include a maximum number of 30 students.

Virtual Classroom

A virtual classroom is a term that has been used interchangeably with online learning. It typically refers to an online course delivered by an instructor synchronously in real-time, for example through video conferencing. The NTDETAS recognize that a virtual, online, synchronously delivered, classroom is an option for delivering the 10 hours of additional instruction or more to move from the traditional 30 hours of classroom learning toward a minimum of 45 hours within a blended program.

Deliberate Practice

Deliberate practice is defined as purposeful, mindful exercises to improve in a skill/domain with repetition and continuous refinement; in particular, arduous activities designed to improve skills progressively over an estimated minimum of 10 years preparation to achieve expert performance at the highest level (Ericsson et al., 1993). Driver education and the NTDETAS require students to drive with an instructor and to engage in structured practice hours far short of the thousands of hours to achieve a minimum of 10 years using deliberate practice. It would be unrealistic to adopt the thousands of hours deliberate practice concept, specifically the number of intense practice hours in a driver education context, to develop mastery and produce expert drivers like highly skilled athletes or musicians.

The purpose of driver education is to produce competent drivers who have attained the knowledge and skill level to pass the road test that is the minimum standard for safe driving (Mayhew et al., 2017). Research on rapid skill acquisition underscores the importance of deliberate practice but suggests that far fewer hours are needed to become competent at a skill rather than the thousands of hours of deliberate practice to achieve expert level skills. Rather, an estimated 20 hours of deliberate practice is what is required to sufficiently learn a skill (e.g., Kaufman, 2014). Driver education may have hit its "sweet spot" with 10 hours of BTW driving and instructor guided activities (including homework, feedback to parents on student progress, and remedial needs) and driving practice under supervision of a parent/guardian. Under these conditions, driver education may be a potentially effective means of teaching a beginner to become a competent and safe driver.

A related and important issue is whether acquiring driving experience truly constitutes deliberate practice given it is not for the explicit purpose of improvement in a set of driving skills. Driving experience is a by-product of the need for mobility and is probabilistic learning. This is when drivers learn from their experiences as well as by imitation, being influenced by the behaviors of other people such as parents, peers, and other drivers (Boboshi AB, n.d.). Probabilistic learning and learning by imitation can also have negative consequences, the principle of which are bad habits acquired over time with driving experience. Further thought and efforts are required to identify effective educational/training or corrective methods that could be applied to deal more effectively with driving deficiencies that develop in experienced drivers.

The NTDETAS also promotes the notion of lifelong learning, and driver education is an important component in that process, but there is no guidance about how to foster and encourage continual deliberate practice. Deliberate practice is critical to producing a competent driver. This rests on the quality of instruction from driver education teachers and the professional development of instructors to ensure they are up-to-date and informed about applying deliberate practice techniques and other educational/training methods to enhance learning (e.g., rapid skill acquisition, spiral learning theories and strategies).

Instructional Hours

Traditional or standard driver education courses are comprised of several delivery approaches: classroom (30 hours); BTW (6 hours), hands-on training; and in-vehicle observation as a passenger (6 hours) (Mayhew et al., 2014). In recognition that the traditional 30/6/6 model of driver education may be limited in its ability to effectively teach critical safe driving skills, the NTDETAS, in the first edition of the standards increased instructional hours from 30 to a minimum of 45 hours of classroom, and BTW from 6 hours to a minimum of 10 hours. It further recommended an additional 10 hours or more of flexible instruction (e.g., classroom, range, simulation, observation, BTW). The increased number of instructional hours is in line with a deliberate practice approach and provides an opportunity for driver education to better address the critical risk factors associated with teen driver crashes.

Teacher training/preparation and professional development are an essential part of this solution and may require breaking down barriers and overcoming teacher/instructor resistance to change. The 2023 NTDETAS with the increased instructional hours has the capacity to include new content and blended learning activities to address the safety needs of teen drivers more adequately. In this regard, the latest version of NTDETAS now has the capacity to address emerging issues such as the rapid growth of in-vehicle safety technologies (in particular, advanced driver assistance systems), the move toward automation and electric vehicles, smart phone use while driving, and distracted driving.

Intensive Versus Traditional Delivery of Driver Education

Driver education can be taught over a few days or weeks (so-called crash courses) or spread out over weeks or months. The traditional driver education approach in the United States delivers driver education over several months. The limited scientific evidence in the driver education field suggests traditional driver education based on teaching students over a long period of time produces better student outcomes than intensive, short-term, driver training courses. A review of the general education literature on the distribution of learning and the duration of spacing gaps that separate repeated exposure to information supports this conclusion.

The NTDETAS establishes that classroom education be distributed over a period of 30 days or more, consistent with the traditional, longer-term approach. It also calls for spacing from classroom sessions to sessions outside of the classroom in the form of homework and driving assignments that speaks to the generalization of the subject material and tasks being taught. Having to integrate and apply information learned to real-world driving practice should derive benefits, in part, from spacing effects.

Overlearning and Driver Education

Overlearning relates to the notion of "laboring in vain" and results in diminished or no increases in learning (e.g., practicing a motor learning task over 2 hours and getting burnt out) (Son & Simon, 2012). This finding has relevance for driver education suggesting, for example, that lengthy BTW driving sessions beyond two hours may have counterproductive learning effects.

The literature suggests overlearning is more likely to occur when "cramming" in short, intensive courses. It may have only short-term positive effects on retention for both physical and cognitive tasks, but it has no benefit for retaining knowledge and skills over the long-term. It is not known, however, whether overlearning might have longer-term benefits for specific driving tasks where repetition is applied as a learning method (e.g., braking skills, hazard perception abilities); the issue of overlearning in relation to driver education has unanswered questions. Currently, the NTDETAS do not directly address the issue of overlearning but do promote driver education as the foundation for students to continue a lifelong learning process.

Block Scheduling and Driver Education

An issue in the general education literature that has relevance for driver education is the practice of block scheduling (e.g., 90-minute class periods) compared to traditional scheduling (e.g., single, 45- or 60-minute class periods), which has been used in high schools in the United States for decades. The reason behind block scheduling was that it resulted in fewer classes and was less overwhelming for students. It was also a more effective use of school time than the traditional single-session approach (Gruber & Onwuegbuzie 2001). Studies examining the effects of block versus traditional class scheduling, however, have produced mixed results (Gullat, 2006; Gruber & Onwuegbuzie, 2001). But there are circumstances where this scheduling approach appears to work (e.g., in certain high school grade levels, student ages, and knowledge levels) (Labak et al., 2020). Some authors recommended mixing block and traditional scheduling to maximize the effects of the two scheduling approaches based on, for example, high school grade and student age (e.g., Labak et al., 2020; Childers & Ireland, 2005). A key factor in the success of block scheduling is instructor preparation and training.

The NTDETAS do not deal with the issue of block scheduling directly, but they require courses to "consist of classroom/theory instruction with a maximum of 120 minutes per day, and BTW instruction with a maximum of 90 minutes per day per student" (NTDETAS, 2023). In practice, however, driver instructors may not teach to the maximum time limits and may have breaks during the day. Since the research evidence is mixed on the efficacy of block scheduling, and considering the findings showing longer sessions may be effective in one educational setting but not in another, there is little or no guidance on the optimal approach that should be adopted for driver education. The question whether block or traditional scheduling or some combination works best with students in a driver education context is unanswered in the literature.

Technological Approaches

Technology-based learning including online virtual, computer-based (e.g., CD-ROM application) and online independent student learning, simulation, or virtual/augmented reality training, could be beneficial for supplementing content and tools employed in driver education. The increased instructional hours in the NTDETAS enhance the capacity of driver education to adopt new technological tools and other approaches to more effectively educate and train teen drivers.

Simulation Training

Simulation is a technological tool or technique that can be employed for practice and learning/training in relation to many different skill-related activities and domains/fields. It provides a structured, guided learning/training experience and an opportunity for students to practice both simple and complex motor skills, and cognitive abilities in a risk-free environment replicating the real world in an interactive, dynamic manner (Lateef, 2019). The potential advantages of driving simulator training have become more apparent over the decades with dramatic advances and improvements in driving simulator technology.

Notwithstanding the potential advantages of simulation, the validity of driving simulators in replicating on-road driving has been questioned and is not well established in the literature. Regarding transfer of learning effects, research has shown training on a driving simulator improves simulated driving performance, and to some extent, on-road driving skills. However, these studies typically have small sample sizes, raising concerns about their generalizability. Crash-based studies are limited, and although there are some supportive studies, taken together, the evidence is relatively weak because of methodological issues with these studies (e.g., small sample sizes and lack of random assignment). Nonetheless, the case for driving simulator training in a driver education context is conceptually strong and there are potential advantages of using driver simulators as a learning tool.

The NTDETAS includes simulation as one of the delivery modes for the 10 or more additional hours of instruction. The NTDETAS also recommended an increase in classroom instruction from 30 hours to 45 or more hours, and some of these increased hours could be with driving simulation (e.g., to facilitate and deliver instruction to support specific students such as underserved, spectrum, and special needs or accommodations students) (A. Urie, personal communication, 2023). The validity and transfer of learning effects of driving simulation with this high-risk group in a driver education setting has not been established. The use of simulation in driver education should be vetted by subject matter experts in the field of driving simulation, young driver research, and driver education to arrive at a consensus for the minimum standards for driving simulators. The proposed minimum could be piloted with novice teens in driver education settings to determine simulator validity.

Computer-Based and Online Independent Student Learning Approaches to Training

Driving simulation can be applied on devices that range from low to high fidelity. Low-fidelity devices typically operate on personal computers using CD-ROMs, or more often today with software online. They are considered to have lower fidelity because they function without peripheral apparatus (e.g., pedal, accelerator) and are typically not as visually representative of real-world driving. These types of simulation training platforms and techniques have been used to teach higher-order perceptual, cognitive skills, most often some aspect of hazard perception like anticipation, awareness, prediction, response, and maintenance. The need for hazard perception training has emerged from decades of research, including on driver simulators, establishing that young drivers have poor hazard perception skills, and these skill deficiencies are a major contributor to the crashes of teen drivers (MacDonald et al., 2015; Fisher et al., 2017). Hazard perception training programs have generally been shown to improve hazard perception of teen drivers, and such improvements have been the case when measured on computer tests, on driving simulators with an eye tracker, and on-road, in real-world driving. Of some importance, the transfer of learning effects of several hazard perception training programs was evaluated against crashes. These programs were shown to reduce collisions among teen drivers, although in one study findings were mixed: crash reductions were observed for male but not for female teen drivers. Other studies had methodological limitations, principal of which was the lack of random assignment of trained and untrained drivers, so other factors, and not training, might explain the crash reductions.

The NTDETAS include 10 hours of additional instructional hours with several delivery options, and, in fact, identifies, as an example, online independent student learning (e.g., hazard anticipation training) as one of these options. The validity, fidelity, and transfer of learning effects of newly designed or available hazard perception training programs and/or other higher-order skill training programs in driver education settings are outstanding issues.

Virtual Reality and Driver Education

Like simulation, virtual reality (VR) is an immersive, interactive experience that attempts to emulate the real-world environment by engaging the visual, auditory, and tactile senses (Xie et al., 2021). These devices are also more flexible and portable (e.g., the use of headsets, goggles), especially in comparison to high-fidelity, motion-based, fixed-driving simulators (DeLuca et al., 2023; Marks et al., 2014; Mangalore et al., 2019). VR is becoming popular as a learning/training tool in education, health, aviation, military, and workplace settings, for example, in hazardous occupations such as with first responders, to train students/employees in the performance of real-world tasks and procedures (Xie et al., 2021; Stefan et al., 2023). This is because VR training applications are highly interactive and apply a "learning-by-doing methodology" (Jakab, 2018), which contributes to improved retention of information and skill development in a risk-free environment.

Systematic reviews of validation studies on VR training underscored a lack of methodologically sound evaluation, suggesting that findings from existing studies showing benefits should be treated with caution, and a need for further research on the effects of VR training. Larger, well-designed randomized controlled trials to strengthen the evidence about the effectiveness of VR training (Woon et al., 2021) are needed. Taken together, however, the results that emerged from the VR training studies are promising and provide at least some support for the use of virtual reality in driver education/training to teach novices knowledge and skills related to driving safely.

In the NTDETAS, provisions are made for VR as an optional delivery tool in the minimum 10 additional instruction hours. VR training would likely be less expensive than driver simulator training. It could potentially be used in the laboratory phase of the driver education classroom and/or as a learning tool to move from the traditional 30 hours of classroom instruction to the recommended 45 hours. It could also be assigned as homework, for example with the use of portable headsets/googles.

In the NTDETAS, virtual reality is defined along with augmented reality (AR) as one term or concept. Although the definition captures the meaning of VR/AR technology in a broad or general sense, technically, VR differs from AR in important ways. Unlike VR applications, AR users can observe their real surroundings with an AR device, adding to it by overlaying the physical world with a virtual scenario, so users can still control their presence in the real world. In other words, AR is the real world enhanced by virtual objects/images. Like VR research, AR studies have demonstrated this technology has benefits including transfer of learning effects, but it also has the same methodological limitations such as small sample sizes, measures related to skill improvements only on AR tests and/or driving simulators, and self-reported information. Better designed research studies are needed to strengthen the promising results of AR studies. The efficacy of such technological learning tools in a driver education is an outstanding issue.

The decision to use driving simulators, simulation techniques, VR, or AR in driver education may not be to select one delivery tool over the others. It is possible that all or a few of these technological approaches to training could be applied in driver education but for different learning purposes: driver simulator to teach intersection, higher-speed freeway, and nighttime driving; simulation techniques to address hazard perception and other higher-order cognitive skills; VR to cover distracted driving and alcohol/drug impaired driving effects; and AR to teach basic vehicle control skills, vehicle maintenance and rules of the road. Further research, pilot studies, demonstration projects, and/or subject matter expert consultations are needed to identify the optimal applications of these technological learning approaches in a driver education context.

This review of the driver education and general education literature identified studies that support the NTDETAS in relation to three primary issues: the value of blended learning, the use of deliberate practice, and the application of technological approaches.

Blended learning compared to strictly online or face-to face learning has been recognized in the general education literature for several decades as an effective learning strategy in terms of outcome measures such as student/instructor satisfaction, better interactions, and, most importantly, improved student performance. The NTDETAS already incorporate a blended learning approach with several delivery methods (e.g., classroom, BTW), and standards for learning to be delivered by some combination of face-to-face, virtual, and online activities. The NTDETAS and the subject matter experts that developed and updated it, have a solid foundation for adopting a blended learning approach and ensuring there is flexibility in the design of the blend.

Deliberate practice is designed to progressively improve skills over a long time (10 or more years; Ericsson et al., 1993) and was initially studied as a method to achieve expertise in motor skills (e.g., sports, music). It would be unrealistic to adopt this deliberate practice concept in a driver education context to develop mastery and produce expert drivers like athletes or musicians. Rather, the purpose of driver education is to produce competent drivers who have attained the knowledge and skill level to pass the road test, which is the minimum standard for safe driving, and become safe independent drivers over the passage of their driving years.

The literature on rapid skill acquisition suggested 20 hours or more of deliberate practice may be adequate to produce competency in a skill or activity. In this regard, driver education may have hit its "sweet spot" with 10 hours of BTW driving, instructor guided activities (homework; feedback to parents on student progress and remedial needs) and driving practice under supervision of a parent/guardian. Under these conditions, driver education may be a potentially effective means of teaching a beginner to become a competent and safe driver.

Technological approaches, including online, computer-based (e.g., with CD-ROM application) and online independent student learning, simulation, or virtual/augmented reality training, have been shown in the literature to be effective teaching tools for improving skill performance. These tools could be beneficial supplements to content and teaching aids employed in driver education. In this regard, the NTDETAS increased instructional hours from the traditional 30/6/6 model to the 45/10/10 framework. These changes enhanced the capacity of driver education to adopt new technological tools and other approaches to more effectively educate and train teen drivers. The application of technological tools would build on the content and delivery strategies currently employed in driver education, potentially enhancing student performance outcomes and safe driving skills.

The decision of using driving simulators versus simulation techniques versus VR or AR in driver education may not involve selection of one delivery mechanism over the others. It is possible that all or a few of these technological approaches to training could be applied in driver education but for different learning purposes.

- Driver simulator to teach intersection, higher-speed freeway, and nighttime driving.
- Simulation techniques to address hazard perception and other higher-order cognitive skills; VR to cover distracted driving and alcohol/drug impaired driving effects; and AR to teach basic vehicle control skills, vehicle maintenance, and rules of the road.
- The application of technological approaches, however, should be approached cautiously because the many studies that have been conducted demonstrating the benefits of these teaching tools often had methodological limitations (e.g., small sample size, no random assignment of subjects). Further research, pilot studies, demonstration projects, and/or subject matter expert consultations are needed to identify the optimal applications of these technological learning approaches in a driver education context. This is especially critical over the next few years as Gen Alpha teens begin to enroll and take driver

education. Gen Alpha teens will be digital learners, comfortable with technology, and expecting visual, interactive, hands-on, personalized learning experiences.

The NTDETAS have already incorporated teaching methods, strategies, and tools that have the capacity to fill many of the specialized needs of Gen Alpha. More focus should be directed at this generational transition. In addition, more effort should be directed at ensuring driver education programs and driving instructors are prepared and embrace recommended standards and learning approaches catering to the upcoming wave of digital learners.

The NTDETAS are a set of voluntary standards that provide a model to guide the administration and delivery of novice teen driver education programs across the United States. They were designed to assist States and/or organizations to improve the quality and uniformity of driver education programs. These standards were originally published in 2009 by national stakeholders in the fields of driver education, road safety, and young driver research from both public and private sectors under the guidance of the National Highway Traffic Safety Administration. Over the decades, the standards were further reviewed and approved by the Association of National Stakeholders in Traffic Safety Education (ANSTSE); the professional body recognized by NHTSA to maintain the standards (NTDETAS, 2023, p. 5). In 2023, subject matter experts from a variety of fields and State driver education administrators have been actively engaged in updates to the NTDETAS.

The debate surrounding the effectiveness of driver education in reducing crashes and fatalities is indeed longstanding and complex (Mayhew, 1996). While some researchers argue that driver education plays a vital role in equipping novice drivers with essential knowledge and skills, others question its ability to directly affect road safety outcomes. Compton & Ellison-Potter (2008) highlighted the importance of driver education in imparting fundamental understanding of road rules, basic vehicle control, and safe driving practices. These are crucial elements that contribute to a driver's competence and awareness on the road. However, it's acknowledged that there are factors beyond the scope of driver education programs that influence driving behavior and outcomes, such as environmental conditions, individual attitudes, and risk-taking behaviors. The complexity of these issues makes it challenging to isolate the specific impact of driver education on overall road safety metrics like crashes and fatalities.

Considering these challenges, the development and adherence to standardized guidelines, such as the NTDETAS, become essential. These standards serve as a framework for driver education programs, ensuring consistency, quality, and align with best practices. By incorporating expert opinion, empirical evidence, and consensus from the literature, the NTDETAS strive to reflect the most effective approaches to driver education.

Continuously reviewing the NTDETAS is crucial for ensuring their relevance and effectiveness in the evolving landscape of driver education. Identifying research gaps and addressing unanswered questions related to these standards can enhance their veracity and alignment with best practices.

The primary research questions for this project, which were identified by members of ANSTSE and State driver education administrators, related to three broad categories: the value of blended learning, the use of deliberate practice, and the application of technological approaches to driver education. Key questions in each of these three primary categories included:

Blended Learning

- What is blended learning?
- Does blended learning produce better student outcomes than classroom only or online only?
- Is there research to support blended learning?
- Are there variations in design and approaches of blended learning?
- What is the optimal class size in traditional classrooms, online, and blended courses?
- What are the benefits of virtual (online delivery) versus traditional face-to-face classroom?

Deliberate Practice

- What is deliberate practice?
- How much deliberate practice is needed for someone to become an expert, or at least competent, in a complex skill, such as driving?
    - What is the difference between deliberate practice and driving experience?
- Are the number of instructional hours in driver education allocated to classroom and BTW adequate to produce a competent driver with the skills necessary to drive safely (e.g., a minimum of 45 hours classroom; 10 hours BTW)?
- What are the benefits of intensive (massing) versus traditional (spacing) driver education?
- What is the importance of overlearning on retention (i.e., practicing a skill even though you no longer improve)?
- Is block scheduling more effective than traditional, single-session scheduling?

Technological Approaches

- What technologically based approaches might prove useful tools to improve learning outcomes in driver education?
- Is there scientific evidence to support the use of driving simulation as a training tool in driver education?
- What are the learning benefits of online and computer-based/online independent student learning simulation techniques applied in driver education?
- Can virtual/augmented reality training approaches be beneficial substitutes for, or supplements to, content and tools employed in driver education?

The purpose of this report is to summarize the latest research with respect to these three topics, improve the scientific underpinnings of the standards, and prompt changes, if the literature was incongruent with what the NTDETAS recommended. The report also identifies key questions related to the standards not currently answered adequately in the literature. Findings from this work provide ANSTSE guidance in re-examining, updating, and maintaining the standards. The report's findings are also relevant to national and State stakeholders, in both the public and private sectors, interested in using the NTDETAS to improve driver education and teen driver safety.

To identify relevant literature that addressed this report's main topics, key words were taken from the research questions to guide the literature search. Electronic library databases and other sources used in the search to identify and obtain journal articles, conference proceedings, and technical reports included those related to driver education and traffic safety as well as the field of education in general. These included the following.

Electronic libraries and databases:

- Traffic Injury Research Foundation's (TIRF) electronic literature database
- Transportation Research Information System (TRIS)
- University of Guelph library database
- PsycINFO, ERIC- Education Resources Information Center
- Web of Science
- Science Direct
- Google Scholar
- PubMed
- ABI/Inform
- UMI ProQuest Digital Dissertations

Other research repositories:

- National Transportation Safety Board (NTSB): www.ntsb.gov/Pages/home.aspx
- Governors Highway Safety Association (GHSA): www.ghsa.org/
- Institute for Traffic Safety Management and Research: www.itsmr.org/
- Federal Highway Administration (FHWA): https://highways.dot.gov/research/research-programs/safety/safety-rd-overview
- Traffic Safety Research [journal]: www.tsr.international/
- UGA [University of Georgia's Traffic Safety Research and Evaluation Group]: https://publichealth.uga.edu/research/working-groups/tsreg/
- National Academies: www.nationalacademies.org/our-work/transitioning-evidence-based-road-safety-research-into-practice
- Montana Department of Transportation: www.mdt.mt.gov/research/projects/trafficsafety.aspx

- iNACOL[2]**:** www.nsqol.org/
- Association for Driver Rehabilitation Specialists (ADED) https://inaya.cloud/research-repository/

Key academic journals with an education focus

- American Journal of Distance Education
- Journal of Distance Education (Canada)
- Distance Education (Australia)
- International Review of Research in Distance and Open Education
- Journal of Asynchronous Learning Networks
- Journal of Technology and Teacher Education
- Journal of Career and Technical Education Research

ANSTSE members and other subject matter experts who critically reviewed draft sections of this white paper were also asked to identify reports/articles regarding key topics/questions not covered in the initial write-up. This input was added to the studies reviewed and integrated into revised versions of the white paper.

Titles, authorship, and sources were initially screened to exclude duplicate documents. Abstracts were then reviewed to ensure papers/reports focused on the research questions/issues and included in the review related to blended learning, deliberate practice and/or technological approaches in education. Papers identified for full review were organized according to each of the relevant research questions and systematically reviewed by the senior author of this white paper.

A critical issue pertaining to the discussion in the following sections on blended learning, deliberate practice, and technological approaches to education was the upcoming transition from Gen Z to Gen Alpha (born 2010-2025) drivers. Gen Alpha are more oriented to digital learning and technology and will start taking driver education in the next few years. The standards and driver education programs need to prepare for the influx of Gen Alpha teens whose learning preferences include visual, interactive, hands-on, and entertaining delivery methods as well as collaborative, personalized experiences, and social-emotional support learning (e.g., to manage emotions and relationships) (Navigate360, n.d.; Zmuda, n.d.).

The learning methods and tools discussed in this white paper are relevant to the NTDETAS and to this generational transition, especially online, blended programs, deliberate practice strategies, and technological tools. This latter category includes driving simulation, simulation techniques (online, interactive, online independent student learning, blended learning), and virtual/augmented reality (interactive, immersive, personalized experiences).

[2] In 2019 iNACOL changed its name to the Aurora Institute. The acronym iNACOL stood for International Standards for Quality Online Teaching.

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Blended Learning in the Context of the NTDETAS

This review of the literature in the fields of driver education and education in general addresses research issues and information gaps found in the previously released NTDETAS, which were developed and recently updated by subject matter experts. In this section of the review, the focus relates to the relationship between blended learning, driver education, and the NTDETAS. Specific questions being addressed include these questions.

- What is blended learning in relation to the NTDETAS?
- Are there benefits of driver education being delivered via blended learning?
- Are there variations in design and approaches to blended learning?
- What are the appropriate time allocations for face-to-face (NTDETAS, traditional approach) and online in blended learning?
- Is there an optimal class size for classroom, online, and blended learning?
- How does virtual learning work in a blended classroom?

Background

Blended or hybrid learning has garnered a growing amount of attention in the past few decades, although the concept has been around for more than 150 years. As early as the 1840s, Sir Isaac Pitman was reported to have initiated the "first distance education course" (Singh et al., 2021; p.145), and later in the 1920s this idea was described as "supervised correspondence study" (Ates, 2009, p. 218).

Blended or hybrid learning has become a key focus of educational strategies, including driver education, in the past few years. The COVID-19 pandemic, which resulted in widespread social distancing, essentially halted classroom teaching. Consequently, some States turned rapidly to permit the implementation of blended courses to fill the gap. In driver education, this typically involved virtual online delivery using Zoom or Microsoft Teams to facilitate instruction and learning in a COVID-free environment. Initially, these programs were intended as a temporary substitute for face-to-face teaching environments that were shut down with school closures and stay at home mandates. However, despite pandemic-related policies subsiding, and more normalcy returning to social and educational institutions, blended learning has remained embedded in teaching/delivery methods.

Even prior to the pandemic, Watson (2008, p. 3), in the iNACOL report, stated "blended learning, combining the best elements of online and face-to-face education, is likely to emerge as the predominant teaching model of the future." Ring et al. (2010) echoed this perspective, emphasizing that the integration of technologies to facilitate the delivery of education, including driver education (DE), will become commonplace in the future.

Blended Versus Hybrid

The terms blended and hybrid learning share a common idea of combining face-to-face interactions in a classroom with online or web-based learning. However, Singh et al. (2021) highlights an important distinction in that blended approaches do not use online activities as a substitute for face-to-face class time but instead are included to augment or build on classroom teachings. In contrast, hybrid courses use online activities as an alternative to face-to-face interactions. These activities can either be synchronous using, for example, real-time meeting sessions, or delivered asynchronously where students learn content on their own schedule without an instructor.

It is important to note that blended and hybrid learning distinctions in the education literature have been, to some extent, blurred or applied interchangeably (Watson, 2008). Moreover, at times these terms have been poorly defined without any clear distinction acknowledged between these different delivery approaches. To ensure clarity in this current review, the term "blended" refers to a learning approach involving face-to-face and online activities, and online activities that supplement and/or substitute for what is taught face-to-face in the classroom. This definition is consistent with the practice adopted in the NTDETAS where these two terms are used together (i.e., blended/hybrid) and hybrid learning is defined in the glossary by referencing the definition of a blended course (NTDETAS, 2023).

The literature on blended learning is quite extensive, partially because of variations in how blended learning is defined, or poorly defined. Consequently, at times there can be ambiguity with respect to what conclusions can be drawn with certainty (Hrastinsk et al., 2019). It has even been suggested by Hrastinski et al. that such broad definitions mean a broad variety of approaches can be described as blended learning.

Mixed Teaching Methods and Active Learning

Although blended learning is defined broadly in the literature, most often, this learning approach has been explained as combining elements of both classroom and web-based learning using different modes of delivery (Means et al., 2009; Zhao et al., 2005; McGee & Reis, 2012; Cleveland-Innes & Wilton, 2018). One of the notable benefits of this model is that the mixed method of teaching enables students to learn with different tools and environments and better develop expertise in the skills being taught (Cleveland-Innes, 2017).

A key feature of the blended, mixed learning approach is the heavy emphasis on active learning with a particular focus on how students learn rather than just content knowledge. Active learning involves teaching approaches that actively engage students with the lesson content such as by means of discussions, problem-solving, case studies, role-playing and other interactive methods. More responsibility is placed on learners than on passive approaches (e.g., lectures), although instructors are still critical to the success of active learning. The length of active learning activities typically varies from a couple of minutes to an entire class session or over two or more class sessions (Queen's University, n.d.) **Error! Hyperlink reference not valid.**. This helps build engagement among students with an interpersonal connection, underscoring the continued importance of the classroom and in-person interactions in the learning process.

Scope of Blended Learning

The meaning and scope of blended learning in the literature has varied from just a few approaches to a variety of delivery methods and modes. At the most rudimentary level, a blended learning experience combines online and off-line learning in which online learning typically means web-based with an internet connection whereas offline learning relies on the more traditional classroom interaction with face-to-face interactions (Singh & Reed, 2001; Akkoyunlu et al., 2006). As observed by Cleveland-Innes and Wilton (2018, p. 2), due to advances in technology-based educational strategies in the past few decades, "the mantra anytime, anywhere describes the new wave of education" available to students. These authors also underscore that, notwithstanding these technological advances, instructors remain a vital component of blended learning initiatives. A broader scope of this learning approach has been put forward by Rossett et al. (2003) who proposed that blended approaches are designed to include tools such as coaching from instructors, web-based classes, informal interactions with colleagues, independent reading, descriptions of competencies, the use of manuals, seminars, and engagement in online groups.

Implications of the NTDETAS

Regardless of whether simple or complex definitions of blended learning are applied, the NTDETAS already incorporates a blended learning approach in several ways. First, the NTDETAS call for several delivery methods with minimum instructional hours, including classroom (45 hours), and BTW training (10 hours), as well as 10 additional hours using a variety of delivery modes, not limited to, observation, behind-the-wheel, range, simulation, classroom/theory (e.g., traditional, online, virtual, hybrid) online independent student learning; and virtual/augmented reality. Even traditional driver education, which dates to the 1930s (Mayhew et al., 2002; Lonero and Mayhew, 2010), applies a blended delivery approach with the 30/6/6 model (i.e., 30 hours classroom, 6 hours observation and 6 hours behind-the-wheel). Other delivery modes historically applied in driver education included a hands-on driver training tool; a precursor to a driving simulator, called the Aetna Drivetrainer. Students could also practice driving using off-road driving ranges (Tate, 2017). Much of this blended learning approach, especially the 30/6/6 model, is very consistent with traditional driver education programs offered in the United States today.

The NTDETAS also accommodate a form of blended learning because, in their redesign and enhancement, the NTDETAS explicitly provide standards for learning to be delivered by some combination of face-to-face, virtual, and online activities. This is in marked contrast to typical practice in several States in which one or more online driver education courses are approved or accepted as an alternative to traditional, in-classroom instruction (Hamilton, 2011).

It is also noteworthy that the original 2009 version of the NTDETAS only focused on administrative and delivery standards for face-to-face classroom and BTW driver education. Since the 2017 revisions, and in the more recent 2023 update to the NTDETAS, online education has become integral to the delivery of driver education, both as a supplement to face-to-face classroom activities. These updates demonstrate that the NTDETAS have adopted a blended learning approach for driver education moving forward.

The Benefits of Driver Education and Blended Learning

Driver Education Effects

The benefits of driver education have been debated over several decades (Mayhew et al., 2002; Lonero & Mayhew, 2010). For a comprehensive review of the issues included in this debate, use NHTSA's Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices, 11th edition (Kirley et al., 2023). This guide references effective, scientifically based traffic safety countermeasures. In a recent review of pre- and post-driver education programs for young and older drivers, Akbari et al. (2021) concluded driver education was not an effective strategy to reduce injuries or crashes. They based this determination on a lack of solid evidence. However, other evaluations of driver education programs, (Oregon

(Mayhew et al., 2014), Nebraska (Shell, et al., 2015), and Georgia (Strategic Research Group, 2021) demonstrated driver education reduced crashes among young drivers. Oregon, Nebraska, and Georgia modified and improved their driver education programs (e.g., lessons on risk prevention/awareness, some form of parental involvement, online instruction; Mayhew & Robertson, 2021). Taken together, these program changes and study results suggest enhanced driver education holds promise for reducing collisions. As described by TIRF (2022, p.1), "all four studies applied evaluation methods that improved upon earlier study designs, including the use of large populations rather than the small samples typically used in randomized evaluation studies, which are prone to sample attrition and reduced power. These studies also controlled for key demographic variables, which was not always the case in earlier investigations."

Despite the promising outcomes of these findings, these studies represent just three evaluations with their own methodological limitations. This small convergence of evidence, while promising, is insufficient to completely challenge results of myriad previous studies that have failed to demonstrate solid and consistent evidence establishing the positive safety effects of driver education. Considering the systematic review findings, Akbari et al. speculated the reason driver education failed to demonstrate safety benefits may be a consequence of inadequate teaching approaches, insufficient course content, failure to adequately address the needs of students, or lack of focus on the most relevant risky driving behaviors. They argued that modifying the course content and delivery of driver education programs was essential to strengthen road safety outcomes. A similar perspective was expressed by Rodwell et al. (2018, p. 1) in observing that a main criticism of these programs pertained to poor or weak methodological designs and the lack of a strong scientific or theoretical foundation.

Several decades ago, the European Union addressed the lack of theory in driver education by adopting a conceptual framework for driver education called the Goals of Driver Education (GDE matrix; for a description see European Commission for Driver Testing and Training, 2007). This framework consisted of four interrelated and hierarchical stages of the driving task (European Commission for Driver Testing and Training, 2007; indented text below taken from GDE Matrix table, p. 104):

1. "vehicle maneuvering (e.g., car function and control);
2. mastery of traffic situations (e.g., traffic rules, hazard perception);
3. goals and context of driving (motives, route planning); and,
4. goals for life and skills for living (e.g., lifestyle, demographics like age, culture, and social position)."

The GDE matrix was developed based on both expert opinion and literature reviews, which is like the approach that guided the development and updates of the NTDETAS in the United States. According to the Supreme project report (European Commission for Driver Testing and Training, 2007, p. 106), "The [GDE] matrix can be used for defining educational goals and educational content in driver training," and the GDE matrix has been considered, internationally, as "best practice" in quality education. The term quality education is one of the Sustainable Development Goals established by the United Nations in 2015. It has been defined as an educational approach that focusses on the social, emotional, mental, physical, and cognitive development of each student (https://leverageedu.com/blog/quality-education/).

Bartl et al. (2005) conducted a survey of standards for driving instructors in Europe and determined that most countries focused almost exclusively on the lower stages of the GDE matrix (vehicle control and driving in traffic). A review of the literature also revealed the content of driver education did not adequately address the higher-order knowledge and cognitive skills of the GDE matrix (e.g., sensation seeking, peer pressure, risk acceptance). The authors recommended instructor standards for the GDE matrix to improve the quality of driver education and training.

The European Union also recommended more active learning approaches and coaching strategies for driver education. For example, they conducted a project from 2007 to 2010 to develop a 4-day training course for driving instructors to let them develop their coaching' skills. This HERMES project (High impact approach for Enhancing Road safety through More Effective communication Skills) was an effort to build on the GDE matrix, focusing on the higher-order cognitive skills in Stages 3 and 4 (Bartl et al., 2010).

Norway was the first country to implement a driver education program using the GDE matrix in 2006. Driver education programs in Sweden and Finland were also based on the GDE matrix. The current literature review was unable to locate information regarding how many and which other European countries adopted some, or all, of the stages of the GDE matrix, as well as using the coaching training course developed in the Hermes project.

Outside of Europe, the GDE matrix has been used in research to develop a best practice checklist and an assessment tool to determine whether driver education programs and driving instructors address the hierarchical driving skill stages of the GDE matrix. In Australia, for example, Watson-Brown et al. (2018) developed an assessment tool based on the GDE matrix to evaluate the teaching styles of driving instructors. The authors observed the lower-level stages of the GDE matrix reflected teacher-centered instruction (i.e., what the teacher or instructor does) and the higher-level stages focused on student-centered instruction (i.e., the student's thinking and activity like self-reflections). Traditional driver education emphasizes mostly teacher-centered instruction (i.e., procedural and control skills) with far less attention given to student-focused approaches that address the higher-order cognitive skills related to the student's goals and motives (Watson-Brown et al., 2018).

More recently, Bailey et al. (2020; 2022), conducted a best practice review based on the GDE matrix of the Australian Automobile Association's national Keys2drive, a single-lesson interactive education program for learners. Their best practice checklist included:

- "having a sound theoretical base,
- facilitating parental involvement,
- provision of feedback,
- building resilience,
- use of coaching approaches,
- commentary driving,
- self-assessment,

- understanding of risk factors, and
- being supportive of Safe System components" (Bailey, 2020, p. 111).

The authors reported that Keys2drive incorporated nearly all these GDE matrix principles. A key recommendation emerging from this checklist assessment involved greater reliance on interactive methods of learning. Recently, however, the Australian Automobile Association in a media release (January 25, 2023) announced that after 14 years in operation the Keys2drive program was being discontinued effective June 30, 2023, due to failures of independent appraisals to identify any safety benefits.

Although the GDE matrix holds promise as best practices, especially from a theoretical and conceptual perspective, and because it is based on scientific evidence and expert opinion, our literature review was unable to identify evaluation studies demonstrating driver training based on the GDE matrix produced road safety benefits in terms of collision reductions among novice drivers. Of interest, a recent literature review that included evaluation studies of initial professional driver training in Europe, as well as elsewhere, reported that such programs overall failed to produce lower crash rates among young drivers (Helman et al., 2017). Several Australian studies, however, have since shown that higher-order learning focused more on cognitive driving skills is associated with safer driving intentions and behavior (e.g., less risky driving, better speed management; Watson-Brown et al., 2018; Molloy et al., 2018; Bailey et al., 2020).

In the United States, like in Europe, driver education has traditionally focused on the more functional principles of the GDE hierarchical matrix (i.e., car function and control, mastery of traffic situations), some aspects of Stage 3 (i.e., goals and context of driving), and to a much lesser extent, the higher-order knowledge, and cognitive skills of Stage 4 (i.e., goals for life and skills for living). The focus on the functional aspects of driving in U.S. early driver education programs was illustrated by the Dekalb County, Georgia, evaluation of driver education conducted in the 1980s. This investigation involved the development of the Safe Performance Curriculum, which was based on a comprehensive driving task analysis, intended "to represent the 1970s state-of-the-art driver education, both in terms of content and methods" (Lonero & Mayhew, 2010, p. 20). In a series of reports, McKnight and Adams (1970) developed a set of instructional objectives for driver education courses based on research involving an analysis of the driver's task, a reduction of these tasks into their component behaviors, and an assessment of the criticality or importance of each of these behaviors to safe and efficient driving (McKnight & Adams, 1971). In the initial driver task analysis, authors identified over 1,500 specific driving tasks.

Although the primary focus in U.S. driver education has been on teaching the functional aspects of driving, some attention has been given to the GDE matrix and higher-order priorities. In this regard, a few driver education programs have used the GDL matrix in developing and/or upgrading their curriculum. The Washington State Department of Licensing and the Office Superintendent of Public Instruction, for example, produced a report (2018) titled *Driver Training: Required Curriculum* to support consistency in programs across the State. In this report, the GDE matrix is described in detail and instructors are encouraged to use the GDE matrix as both a teaching tool and a means to measure how well they are accomplishing a paradigm or cultural shift in which students are challenged to assess their own self-awareness, self-control, and driving abilities. Consistent with the GDE matrix, the Required Curriculum (p. 1) is as follows.

- "Student-Centered (focused on student, not teacher)
- Outcome-Oriented (students must demonstrate learning)
- Attitude/Behavior-Based (more than just knowledge)
- Focused on Driver Self-Reflection (how do I relate to this information?)"

The AAA How to Drive curriculum (n.d.) also applies and integrates the GDE Matrix in its driver training program (e.g., B. Van Tassel, personal communication, 2023). For example, in relation to Level 4 of the GDL matrix (Goals for Life and Skills for Living), the curriculum includes self-reflection on expected driving skill, assessed at the beginning and end of program, a personal driving plan, and emotion-based driving scenarios.

These are all positive steps to improve driver education from a conceptual to a more holistic perspective in the United States. The primary focus to improve State administration and delivery of driver education in the United States, however, has involved the development, promotion, and maintenance of the NTDETAS. These voluntary standards were the result of a concerted effort by national stakeholders to upgrade and enhance the administration, delivery, and content of driver education. To illustrate, the delivery methods and content increased (e.g., 45 hours of classroom instead of the traditional 30 hours classroom) and additional elements of blended learning (face-to-face-classroom, virtual, and online learning) were integrated into the NTDETAS.

The literature search identified only one evaluation conducted in the field of driver education that recently evaluated the relative effects of different delivery methods, including online versus classroom. A study conducted in Georgia examined the effectiveness of the Georgia Driver's Education Commission scholarship program and different tools used to deliver it in reducing crashes and convictions among young drivers (Strategic Research Group, 2021). This study revealed that teaching in the classroom combined with hands-on, in-vehicle instruction produced a reduction in convictions, crashes, serious injuries, and deaths as compared to other mechanisms of delivery. These other mechanisms included in-classroom training in conjunction with a parent/teen driving tool, web-based courses combined with lessons from an instructor in-vehicle, and online training courses using a parent/teen driving guide. Although the Georgia study demonstrated support for classroom instruction over online education, it was not an explicit investigation into the safety effects of a blended program; in other words, it did not compare a blended program involving both face-to-face classroom and online features with face-to-face only or online only.

The general education literature provides a wealth of information about the benefits of blended learning and possible insights that may be useful in support of the NTDETAS.

Blended Learning Effects

Blended learning, compared to strictly online or face-to face learning, has been recognized in the general education literature for several decades as an effective learning strategy (e.g., Means et al., 2009). This is true in terms of outcome measures such as student/instructor satisfaction, better interactions, and, most importantly, improved student performance. Studies on student satisfaction with blended learning have generally shown very positive results for several reasons, including the convenience of this mixed learning approach and the ability of students and instructors to better manage the pace of learning (Kenney & Newcombe, 2011). In a study of student performance in, and perceptions of, a blended classroom course, Webster et al. (2020) noted substantial improvements in the degree of student engagement, their perceptions, and overall achievement in the blended classroom. They also reported, based on surveys of students, much higher levels of enthusiasm, stimulation, self-perception of the amount of knowledge gained, perception of the value of activities contained in the course activities, and the overall effectiveness of the content and tools used in the blended classroom.

Tayebinik and Puteh (2013) contended that blended learning is more favorable than online learning because it provided advantages for learners, including being a part of a community. Their study indicated that "blended learning was an efficient approach of distance learning in terms of students' learning experience, student-student interaction as well as student-instructor interaction, and is likely to emerge as the predominant education model in the future." Wicks et al. (2015) identified other benefits of blended learning such as:

- minimizing face-to-face interaction,
- being preferred by faculty members,
- offering more self-directed learning and collaboration among students,
- enabling teachers to observe learning in diverse environments like the job market, and
- providing students with more control of learning.

They also observed that blended learning increases student participation, has a positive effect on completion of higher education, and improves grades. However, they further noted that achieving these effects can be influenced by several factors such as students' age, background, and school attendance as well as the specific approaches to blended learning activities.

Earlier research on methods of delivering education clearly established that blended learning produces better student outcomes than online only or classroom only. Rossett et al. (2003) described a study by Peter Dean et al. (2001) that noted that using a variety of interconnected strategies for students offered in conjunction with in-class teaching resulted in greater learning. Similarly, Singh and Reed (2001) reported that research demonstrated that reliance on several tools in a blended learning model improved the general effectiveness of a learning program.

The benefits of blended learning on student performance have also been established in a meta-analysis evaluating evidence-based practices in online learning. Means et al. (2009), in this review of online studies, reported that:

- "Students who took all or part of their class online performed better, on average, than those taking the same course through traditional face-to-face instruction. Learning outcomes for students who engaged in online learning exceeded those of students receiving face-to-face instruction" (p. xiv).
- "Instruction combining online, and face-to-face elements had a larger advantage relative to purely face-to-face instruction than did purely online instruction." (p. xv).

This meta-analysis revealed that online learning outperformed face-to-face learning but, importantly, blended learning that integrated online with face-to-face, produced even better student outcomes; students taught in a blended program had, on average, 35 percent better performance than those taught face-to-face (Slomanson, 2014). The authors cautioned, however, that other factors may explain these positive results for a blended learning approach, including differences in course content, teaching skills and methods, and instructional hours.

The authors of this meta-analysis concluded that in studies contrasting blends of online and face-to face instruction with conventional face-to-face classes, a blended approach typically has better student outcomes. This consistent finding provided strong evidence to support adopting a blended learning approach. They also underscored the small benefits of online learning only over face-to-face learning. Means et al. (2009) observed this was especially the case when students in the online course spent more time on task than those in face-to-face classrooms. The results of this meta-analysis also suggested the effectiveness of online learning approaches appeared quite broad across different content areas (a wide range of academic and professional studies) and learner types (under graduates, graduates, and professionals). A more recent meta-analysis reported finding no significant differences between online and face-to-face classroom learning on student performance but did not examine the relative merits of blended learning over the other teaching methods (Woldeab et al., 2020).

In their review of the international literature, Smith and Hill (2018) identified the benefits of blended learning, which included:

- increased flexibility for staff and students;
- personalization;
- enhanced student outcomes;
- the development of autonomy and self-directed learning;
- opportunities for professional learning;
- cost efficiencies;
- instructor and student satisfaction; and,
- increased interaction between instructors and students, as well as between students.

They also observed that evaluation studies demonstrated blended learning has many benefits that go well beyond improvements in student outcomes, greater satisfaction, and course engagement as well as better motivation to learn. They found, for example, different types of students can benefit from blended learning, including non-traditional, international, and students on placement. Blended learning also provided opportunities for enhanced interaction between different groups (e.g., national, and international experts) that authors suggested supported the role blended learning can play in fostering collaboration, connection, and community building.

More recently, Singh et al. (2021) described the effect of the pandemic on educational institutions, including school closures and sheltering at home policies, with the transition to, and adoption of, online learning as a necessary means to continue instruction. During this public health crisis and restrictive period, the authors identified several benefits of online learning as including:

- “flexibility,
- ability to work at your own time and pace,

- engaging learning experience,
- self-directed learning,
- cost effectiveness, and
- ability to produce in-depth discussions” (p. 142).

The authors observed that as the COVID-19 restrictions were lifted, blended learning was a natural evolution as students and instructors could return to the classroom and continue to garner the benefits from online activities.

Of some relevance to the use of blended learning in driver education, a few studies suggested the positive effects of blended learning vary depending on the type of course. Wicks et al. (2015), in an exploratory case study, noted students in two university courses, engineering and cognitive psychology, were more satisfied with their experience and reported greater satisfaction with the blended course. The authors observed these results were consistent with past research where online courses were shown to be more beneficial for students in applied courses. They concluded this was consistent with their findings because these two courses had applied activities as students spent time “designing and building rather than discussing mathematics or physics in a pure form” (p. 61). This is highly relevant to driver education and the NTDETAS that integrates both theoretical or pure education via face-to-face classroom and online along with “practical” or applied instruction in BTW training and driving simulation. Wicks et al. cautioned, however, that the differences in students' experiences in applied courses could relate to other factors such as a difference in the course instructor or in the types of students taking the courses rather than differences in course type.

Limitations

Although blended learning has been shown in the literature to have significant benefits, including improved student performance, particularly in courses with applied components, there are some important limitations. There is some evidence, for example, suggesting students taught online are more likely than those in a traditional face-to-face classroom to drop-out of the course (Mohammed et al., 2016). This criticism, however, relates to online institutions and not to a blended learning context that combines face-to-face classroom and online, which has been shown by Wicks et al. (2015) to have a positive effect in reducing dropout rates in higher education. The literature review also identified several other weaknesses of blended learning, or typically the online component of blended learning:

- lack of spontaneity;
- more procrastination by students;
- limitation of resources;
- lack of automation;
- large amount of teacher content preparation;
- security and privacy concerns;
- lack of internet access and technology;
- lack of digital literacy;

- capacity limitations (e.g., limits on the number of simultaneous users or minutes per month);
- more time-consuming;
- instructor resistance;
- concerns about academic quality;
- insufficient funding/costs;
- lack of student buy-in;
- minimal interaction; and,
- timeliness of interaction (Cleveland-Innes & Wilton, 2018; Graham, 2004; Kumar et al., 2021; Niemiec et al., 2017; Singh et al., 2021).

In-person classroom weaknesses have also been discussed in the education literature, including low participation rates and the lack of flexibility, largely because of large class sizes and the limited time available to cover content (Graham, 2004). In the design of blended learning, however, the weaknesses of each learning component (in-person and online) could be addressed directly and rectified or could be counterbalanced by the strengths of the other component, to achieve the best of both worlds (Hrastinski, 2019).

Variations in Design and Approaches of Blended Learning

Blended learning has been described as a continuum ranging from fully face-to-face classroom to all online activities with many different varieties and tools included within this approach (Watson, 2008). According to McGee and Reis (2012), blended course designs are varied and although this learning approach has been shown to positively affect a range of student outcomes, the attributes of a successful blend remain elusive. In this regard, Cleveland-Innes and Wilton (2018) observed the proportion of online and face-to-face in a blended program are determined by the curriculum, content, and course objectives. They also summarized the process for achieving a successful blend:

> "In a quality blended learning experience, the content and activities of both in-person and online learning are integrated with one another and work toward the same learning outcomes with the same content. The various learning experiences are synthesized, complement each other, and are planned or orchestrated to run in parallel. These systems of instructional design use many types of teaching and learning experiences and vary in design and implementation across teachers, programs, and schools. The potential variations of mixed-mode learning are virtually endless…" (p. 2).

Cleveland-Innes and Wilton (2018) also argued the subject matter and course features dictate the type of blend to apply "one size does not fit all" (p.18). From their perspective, designers and instructors need to consider the course content, the learners' needs, and the curriculum requirements to build an integrated, blended (mixed mode) course. In this regard, Ma'arop and Embi (2016) in discussing challenges faced by instructors in implementing blended learning, observed an important difficulty to overcome is finding the right blend of face-to-face and online learning. Thus, the success of blended learning depends on fully integrating online and in-person activities into an overall design and implementation strategy, to enhance instructor teaching and student learning and not to simply introduce new technologies into the classroom (Cleveland-Innes & Wilton, 2018).

Models of Blended Learning

The literature describes not only a range of designs/approaches of blended learning but also a variety of models. Some authors have argued that, in the best-case scenario, blended learning should be highly personalized to ensure each student has a blend that addresses their individual learning needs and considers key influencing factors such as age and life circumstances. Cleveland-Innes and Wilton (2018) described this personalized approach for blended learning as an "à la carte model (p. 15)." According to these authors, "this model lets students have more control over their learning" experience by, for example, choosing what to take online and in the classroom, when to go to classes and when to engage in other learning activities such as watch online or in class videos, download reading or other assignments, and start/complete assignments.

The personalized "à la carte model," however, is not the only blended learning model. As with the wide variations in design approaches to blended learning, the literature has also produced myriad models for blended learning. Wicks et al. (2015), for example, cited Garrison et al., (2001) in describing a theoretical framework called the "Community of Inquiry" that has been used to enhance learning outcomes in both online and blended courses. This framework facilitates online learning through three interdependent methods:

- social presence (i.e., establish a community of learners to ensure students don't feel isolated when learning online and promote feeling safe in the sharing of ideas so that students collaborate with others on course content and activities),
- teaching presence (i.e., instructor is responsive to students' need); and,
- cognitive presence (i.e., learners can construct and verify meaning through reflection and discussion).

McGee and Reis (2012) cited a study by Yukawa (2010) that described a "Community of Practice" model that takes a personalized approach, like the à la carte model, letting students make decisions about the lesson plan, learning activities, and recording and sharing student outcomes. The authors also cited Picciano's (2009) multi-modal model that focused "on content, social-emotional supports, dialectic questioning, higher levels of thinking, collaboration, and reflection" (p. 15). In a recent paper on blended learning tools and practices, Kumar et al., (2021) provided details on the following blended learning models.

- Station Rotation Blended Learning (SRBL)
- Rotation Blended Learning
- Remote Blended Learning (RBL)
- Flex Blended Learning (FBL)
- The "Flipped Classroom" Blended Learning (FCBL)
- Individual Rotation Blended Learning (IRBL)
- Project-Based Blended Learning (PBL)

- Self-Directed Blended Learning (SDBL)
- Inside-Out Blended Learning (IOBL)
- Outside-In Blended Learning (OIBL)
- Supplemental Blended Learning (SBL)
- Mastery-Based Blended Learning (MBL)
- Enriched Virtual Model

Further information about blended learning models can be obtained from many other reports and papers (e.g., Anthony, 2019; Caraivan, 2011; Cleveland-Innes & Wilton, 2018; Graham, 2004; McGee & Reis, 2012; Ossiannilsson, 2017; Singh & Reed, 2001; Singh et al., 2021, Slomanson, 2014; Rossett & Frazee, 2006; Hrastinski, 2019).

Implications for the NTDETAS

Suffice it to say, there is no shortage of models that can be applied to design and tailor a potentially effective blended learning course. The NTDETAS, and the subject matter experts that developed and updated it, have a solid foundation for adopting a blended learning approach and ensuring there is flexibility in the design of the blend. This flexibility in design lets State driver education administrators tailor their programs to address the needs of students in their State and adopt and blend teaching tools best suited to augment and build upon the abilities and experiences of their driving instructors to achieve course objectives.

Time Allocations for Blended Learning

Given the varied design of blended learning, it is not surprising there is no consensus about the time split between face-to-face education and online activities. In fact, the literature provides little guidance on this issue. The lack of attention to prescribing rules or guidelines for the distribution of time allocated to face-to-face and online in a blended course is fully intentional. From the perspective of Cleveland-Innes and Wilton (2018, p. 20), blended learning courses should be designed "without prescriptions or guidance on the time allocations for face-to-face versus technology-mediated learning." Similarly, Watson (2008) observed there is no formula for establishing what percentage of time should be reserved for in-person, and what percentage should be reserved for online learning. A similar conclusion was reached by McGee and Reis (2012) in their review of blended learning, and they reported considerable variability in time allocations for online and face-to-face. To illustrate, "a range from 30 to 79 percent in either online or face-to-face; blended courses ranged from between 90-10 and 10-90 distributions of face-to-face and online sessions" (p. 9).

Guidance on Establishing Time Allocations

There has been at least some effort to set time allocations in blended learning environments, but there is little consistency across studies and practices in educational institutions. According to Slomanson (2014), for example, the American Bar Association's distance learning standards is two-thirds of instruction in the classroom and not more than one-third of instruction outside of the classroom. In an earlier paper, Brandt et al., (2010, p. 167) defined blended learning as involving "…synchronous (real time) or asynchronous (anytime) learning with more than 20 percent face-to-face time." In a more recent paper, Martin et al. (2020) described a blended face-to-face model as consisting of up to 70 percent of the course engaged in face-to-face learning with 30 percent of the course taking place online. The Sloan Consortium defined blended courses as having between 30 percent to 79 percent of their content delivered online, with the remaining portion of the course content delivered by face-to-face instruction or other methods, such as videos and paper textbooks (Wicks et al., 2015). Like the Sloan Consortium, Hrastinski (2019) referenced Allen & Seaman (2010) as suggesting there should be a range of 30 percent to 79 percent online in a blended course. These authors also described a course from the literature that included two hours per week in a computer lab, and two hours per week synchronously and asynchronously on the internet. According to Arzt (2011), the standard time ratio for blended learning is two hours online for every hour of face-to-face in class. Other authors such as Pizzi (2014) and Saparas et al. (2018) adopted a more balanced time division with 50 percent online or virtual and 50 percent face-to face for the classroom.

Implications for NTDETAS

The variability in time allocations emerged from the perspective that "blended learning combines the best of both worlds of online and classroom instruction through curricular design that selects the best teaching strategy to accomplish the intended student learning outcomes" (Brandt et al., 2010, p. 167). According to Cleveland-Innes and Wilton (2018), the context of the course determines the time allocations for online and face-to-face activities. These authors also underscore the importance of including both synchronous (real-time) and asynchronous (time-dependent) activities in a blended learning environment. All this suggests the blended learning literature generally supports the approach adopted in the updates to the NTDETAS on the allocation of time in the classroom. The 45-hour minimum requirement is flexible and can be delivered face-to-face (i.e., traditional), online, virtual, or blended. And this standard emerged from subject matter expert opinions, experiences, and understanding of content, teaching strategies, and student needs. Even so, further efforts are needed to ensure blended delivery of driver education is properly integrated, with the "best" balance between in-person and online learning activities and works synergistically to optimize student learning outcomes. Further research is needed to ensure the proper blend is achieved in driver education, i.e., a mixed-learning approach that produces safer drivers than would have otherwise been the case with traditional approaches or technologically "alluring" online methods, applied alone.

Class Size in Traditional Classrooms, Online, and Blended Courses

Class size is a critical issue for blended learning as it has been for decades regarding face-to-face classrooms and, more recently, in online only courses. As observed by Alvarez (2020, p. 122) "class size plays an important role for teaching and learning delivery because it affects the way teachers teach and manage the learning environment."

In Traditional Classroom

The issue of class size in a traditional face-to-face classroom, however, has been contentious, primarily due to concerns about institutional costs, teacher overload and burnout, as well as achieving student interactions and academic success. Research generally suggests that small class size is preferable to large class size for a variety of reasons. Large class size has been shown to negatively affect active participation and interaction between students and instructors that are critical factors to achieve student/instructor satisfaction and achievement. Instructors in larger classrooms often must rely on teaching in a lecture-style resulting in little interaction with, and participation from, students, and minimal student-to-student interactions, which is critical to fostering cooperation, communication, and learning (Kenny & Newcombe, 2011).

School budgeting is also a key issue in discussions about class size primarily because higher costs are typically associated with smaller class sizes. This is because more teachers must be trained and are needed to teach classes with fewer students. The literature suggests public schools typically have a higher-class size than private schools or boarding schools. (Hun School of Princeton, 2019). The Organization for Economic Co-Operation and Development (n.d.) estimated, for example, that the average class size in the United States in 2020 for lower secondary education in public educational institutes was 26 students. This compares to an average class size in private educational institutes of 15 students. The difference in student-teacher ratios between public and private schools likely reflects that private schools can afford and manage smaller class sizes because students attending private schools come from, on average, higher income families who typically can bear the cost of higher tuition fees.

Whitehurst et al. (2011), in a report titled *Class Size: What Research Says and What it Means for State Policy*, observed that in recent decades (i.e., prior to 2011, the publication date of the study), at least 24 States had mandated or rewarded class-size reduction (CSR). This policy change towards class size reductions emerged from research showing smaller classes increase student learning. The authors referenced what they characterize as “the most influential and credible study” (the Student Teacher Achievement Ratio, or STAR, study, see Mosteller, 1995). This study was conducted in Tennessee during the late 1980s and it revealed that class size reduction (from 22 to 15 students) increased student achievement after a 4-year period by about 3 additional months of schooling. Whitehurst et al. also reported that other studies have shown benefits or mixed results of small class size and as such firm conclusions cannot be drawn. Based on their review, they concluded that, “When school finances are limited, the cost-benefit test any educational policy must pass is not *does* this policy have any positive effect? but rather *is* this policy the most productive use of these educational dollars?” (p. 1). In this regard, Whitehurst’s group have noted the challenge to State CSR policies is effectively addressing the high cost of small classes. Class size fundamentally becomes a trade-off between institutional costs (i.e., what the school can afford or tolerate) and the degree of student performance that can be achieved, leaning toward as small a class as possible working with the funding resources that are available.

As suggested above, in the discussion of the Whitehurst et al., the importance of class size is reflected in the fact that many States regulate maximum class size or set teacher to student ratios. A review of State regulations on class size, however, reveals considerable variability across, and even within, States. For example, Florida (implemented in 2002) has a maximum of 25 students in grades 9 through 12, and as of the 2015-16 school year the State-wide class averages were 18.92 students per class in high school classes. Virginia State law (implemented in 2016) requires a student teacher ratio of 24-1 in grades 6-12 (English classes only). San Diego, California (implemented in 2014 to 2017) caps secondary classes to 36 students. In Boston, Massachusetts, the maximum class size in grades 9-12 is 35 students (implemented in 2010). New York City caps high school classes at 35 students, although some classes (e.g., physical education/gym or music) have a cap of 50 students (Class Size Matters, n.d.).

In Online Courses

Although there has been some debate in the literature over class size in online courses, the weight of the evidence suggests a class size of 20 to 30 students (Sorensen, 2015). In reviewing the literature, Sorensen, for example, referenced a study by Weick (2014), who recommended online class size should be like in-person class size (about 20 students). Sieber (2005) also found that instructors reported the optimal class size for online learning to be 20 students, with more than that number considered unmanageable. Arzt (2011, p. 12) concluded that "online classes for undergraduate programs can run reasonably well with enrollments between 15 and 22 (assuming a degree of healthy interactions among students, with the instructor, and with the very content are expected)."

Some research also suggests that optimal class size for online learning is related to the instructors' "level of experience," with smaller class size warranted for novices and less experienced instructors (e.g., class sizes of 12 students) (Arzt, 2011; Burruss et al., 2009). As experience in online teaching is gained, class size can increase accordingly. However, there is no consensus on this issue as other studies suggest "The number of years teaching online courses" and "the level of expertise" were not "related to any measure of class size" (Orellana, 2006, p. 4).

However, several studies have reported there are potentially negative effects with both smaller and larger class sizes in online learning. In a review of the literature by Sorensen (2015), larger class sizes were shown to have a negative influence on student-instructor interaction and on effective discussion (e.g., too many responses from students overwhelm the instructor; the instructor and students having difficulty following a discussion). The author also observed that studies have reported negative effects of small class size (5 to 10 students) in that there were "a limited number of perspectives or too few interactions" (p. 142). Sorensen (2015) also conducted a study of the relationship between class size and online instructor performance and noted that as online class size increases, instructor performance declines – e.g., a lower quality of instructional feedback.

Optimal class size for online learning also depends on other factors that influence students and instructors (Burch, 2019). As observed by Burch, "Courses designed from a constructivist perspective, with heavy discussion activities, will likely need to have lower enrollments in order to avoid too much cognitive load for learners (and the instructor!)." Albeit speculative, this is also likely the case for applied or practical training methods, which could be considered components of blended programs, because they may warrant one-on-one instruction as is the case with BTW training.

A few recent studies have focused on online class size for higher education (education beyond high school, especially at a college or university). Thomas and Sritto (2020) referencing an earlier study by Taft et al. (2019) observed there is no "one size fits all" approach for class size in online learning, but certain class sizes may work better for certain course types. Research suggested, on average, that 30 students tended to be preferable in online higher education (e.g., Taft et al., 2019). In a quantitative study to investigate the relationship between class size and student outcomes, Thomas and Sritto (p. 2) reported students in online courses that included 30 or fewer students had higher grades than those in larger classes. Based on these results, the author concluded "It may be beneficial to limit certain kinds of courses to 30 students or fewer, as 30 students may be a tipping point where the benefits of smaller online classes wear off."

In Blended Learning Programs

In their study of a blended learning approach in a fundamental engineering mechanics course, Webster et al. (2020) noted the blended classroom was effective in medium-sized classes not just small classes (i.e., classes with an average of 40 students). They also cautioned of the importance of using teaching assistants as class size increased because instructors find it more and more difficult to connect on a personal, one-to-one level, with individual students as classroom size increased. They emphasized the importance of in-class interactions between small groups of student partners as well as with students and the instructor and teaching assistants.

Conversely, a few authors have argued that large class sizes are actually feasible mainly because blended learning uses technologies and strategies specifically designed for large class settings. Francis (2012) discussed several free- and low-cost Blended Learning Instructional Strategies (BLIS), which are defined as strategies that use mobile learning technologies to engage students with content, the faculty, or their peers. The strategies include:

- using advanced organizers,
- checking for student understanding,
- asking questions during lectures,
- doing Cooperative Learning in large classroom settings,
- completing One-Minute Papers, and
- stopping student web-surfing during large classroom instruction.

Francis concluded that, "Technology applications, mobile handheld learning technologies, and web-based assignments, when united with effective, research-based classroom instruction in the form of [BLIS)] provide an opportunity to address issues related to instruction in the large classroom setting and effectively engage students in meaningful learning opportunities" (p. 151). The author, however, did not provide any evidence that using these technologies and strategies for large class sizes was more effective than blended learning with smaller class sizes in terms of student performance and student/instructor satisfaction.

Implications for the NTDETAS

The literature suggests the optimal class size for blended learning is a small class of 20 to 30 students. This supports the NTDETAS that requires driver education courses to consist of a maximum number of 30 students. The general education literature, however, suggests class size may vary depending on course content, requirements, and design as well as on the level of experience of the instructor. It may also be feasible to increase the class size using technology designed to manage more students in a potentially efficient manner, although the effectiveness of this strategy on student performance appears untested.

Virtual Versus Traditional Classroom

A virtual classroom is ill-defined in the literature. According to Robinson and Beckham (2022), in a presentation on the *Effectiveness of Virtual Classrooms in Driver Education*, a virtual classroom is synonymous with an online classroom. In this regard, they cite Ananthanarayanan (2014, slide 5):

> "In both the popular and scientific literatures, the terms virtual-, online-, digital-, remote-, distance-, and e-learning are used interchangeably and are broadly described as 'any instructional format that is mediated by some form of technology, typically the internet and is characterized by geographical and, sometimes, temporal separation between instructor and learner."

The NTDETAS defines virtual classroom as "classroom instruction delivered via a video conferencing platform, delivered synchronously with a live instructor in real-time allowing for discussion and evaluation" (p. 51). The findings from the general education literature reviewed in the previous sections would, generally, apply to a virtual or online classroom. Studies suggest a virtual (i.e., online) classroom would produce slightly better student outcomes than a traditional classroom or, at a minimum, there would generally be no difference in student performance between these two learning approaches (Means et al., 2009; Woldeab et al., 2020). Lockman and Schirmer (2020), observed that effective teaching strategies work equally well in virtual classrooms and in face-to-face classrooms (e.g., "the use of multiple pedagogies and learning resources to address different student learning needs, high instructor presence, quality of faculty-student interaction, academic support outside of class, and promotion of classroom cohesion and trust"; p. 130). In this regard, Robinson and Beckham (2022) also identified the following important and promising teaching strategies that would apply in the virtual (online) classroom.

- A clear focus for the lesson
- Offer instruction that builds upon itself
- Get the students to engage with the content
- Give feedback
- Two or more exposures
- Have students apply their knowledge
- Get students working together

Discussion and Summary

Blended learning combines face-to-face interactions in a classroom with online or web-based learning. The literature consistently demonstrated that blended learning has significant educational benefits, including teacher/student satisfaction and improved student performance. The NTDETAS already incorporates a blended learning approach in the adoption of several standards, including:

- several delivery methods with minimum instructional hours, including classroom (45 hours), and BTW training (10 hours), as well as 10 additional hours using a variety of delivery modes, such as, but not limited to observation, behind-the-wheel, range, simulation, classroom/theory (e.g., traditional, online, virtual, hybrid), online independent student learning (e.g., hazard anticipation training; and virtual/augmented reality; and
- learning to be delivered by some combination of face-to-face, virtual, and online activities.

In the NTDETAS, online education has become integral to the delivery of driver education as a supplement for face-to-face classroom activities. From this perspective, the NTDETAS has adopted blended learning, which is consistent with best practices in the education field in general, and an optimal approach that is widely viewed in the literature as the wave of the future. The flexibility of the NTDETAS on the use of the delivery modes is also an attractive feature that lets State driver education administrators tailor and refine their programs to meet their needs and unique learning situations.

Benefits

A key question in continued support for driver education, especially in a blended learning environment, is the extent to which established safety and learning objectives are being met. The literature in the field of driver education and in general education, has been examined in a variety of educational settings (Kirley et al., 2023) to determine if there are delivery benefits.

The debate over the benefits of driver education has continued over several decades. Early evaluations showed safety effects of driver education suffered methodological flaws that questioned the veracity of their findings. Better designed evaluations produced mixed results or concluded that traditional programs failed to meet their primary safety objective, which is to reduce or prevent the collision involvement of teen drivers. Even more recent evaluations have attempted to overcome some of the methodological limitations of earlier studies to demonstrate that driver education reduced crashes among young drivers. However, all these studies have limitations, and it is therefore difficult to note if or even how much promise, driver education holds as a proven safety countermeasure.

Notwithstanding the recent encouraging findings on the safety benefits of driver education, some researchers have criticized driver education for lacking a strong scientific or theoretical foundation (e.g., Rodwell et al., 2018). Although there is some justification for this criticism, especially with traditional programs, driver education is not devoid of theoretical or conceptual underpinnings. Several decades ago the European Union (European Commission for Driver Testing and Training, 2007) addressed the lack of theory in driver education by adopting a conceptual framework for driver education called the Goals of Driver Education (GDE matrix). This framework consisted of four interrelated and hierarchical stages of the driving task that ranged from basic skills related to vehicle maneuvering (e.g., car function and control) to higher-order abilities related to the goals for life and skills for living (e.g., lifestyle, demographics like age, culture, and social position).

In the United States, like in Europe, driver education has traditionally focused on the more functional principles of the GDE hierarchical matrix (i.e., car function and control, mastery of traffic situations). A few driver education programs, however, have used the GDE matrix in developing and/or upgrading their curriculum, such as in Washington State (Washington State Department of Licensing, 2018), and the AAA (n.d.) How to Drive curriculum. These are all positive steps towards improving driver education from a conceptual and more holistic perspective. The primary focus to improve U.S. State administration and delivery of driver education, however, has been the development, promotion, and maintenance of the NTDETAS. These voluntary standards were the result of a concerted effort by national stakeholders to upgrade and enhance the administration, delivery, and content of driver education.

Blended learning compared to strictly online or face-to face learning has been recognized in the general education literature for several decades as an effective learning strategy. Indeed, studies contrasting blends of online and face-to-face instruction with conventional face-to-face classes have concluded that a blended approach typically has better student outcomes. This consistent finding provides strong evidence to support adopting a blended learning approach. Studies also underscore the small benefits of online learning only over face-to-face learning.

Of some relevance to the use of blended learning in driver education, a few studies suggest the positive effects of blended learning vary depending on the type of course. Online learning has also been shown to be more beneficial for students in applied courses compared to pure education or theoretical courses. This has important relevance for driver education and the NTDETAS that integrates both theoretical via face-to-face classroom and online along with "practical" or applied instruction in BTW training and driving simulation.

Variations in Design and Approaches

Blended learning has been described as a continuum (Watson, 2008) with considerable variability in design as "one size does not fit all" (Cleveland-Innes & Wilton, 2018, p. 18). As with the wide variations in design approaches to blended learning, the literature has also produced myriad models for blended learning. Indeed, there is no shortage of models that can be applied to design and tailor a potentially effective blended learning course. The NTDETAS and the subject matter experts that developed and updated it provide a solid foundation for adopting a blended learning approach and ensuring there is flexibility in the design of the blend.

Time Allocations

Given the varied design of blended learning, it is not surprising there is no consensus about the time split between face-to-face education and online activities. In fact, the literature provides little guidance on this issue and the lack of attention to prescribing rules is fully intentional. The general rule is that the features and circumstances of the course should determine the time allocations for online and face-to-face activities. All this suggests the blended learning literature generally supports the approach adopted in the development of and updates to the NTDETAS regarding the allocation of time in the classroom. The 45-hour minimum requirement is flexible and can be delivered face-to-face (i.e., traditional), online, virtual, or blended. This standard emerged from the opinions, experiences, and understanding of content, teaching strategies, and student needs of subject matter experts. Even so, further efforts are needed to ensure blended delivery of driver education is properly integrated, with the best balance between in-person and online learning activities and works synergistically to optimize student learning outcomes. An outstanding issue is how to ensure the proper blend is achieved in driver education (i.e., a mixed-learning approach that produces safer drivers) than would have otherwise been the case with traditional approaches or technologically alluring online methods, applied alone.

Class Size

Class size is a critical issue for blended learning as it has been for decades regarding face-to-face classrooms and, more recently, online only courses. The issue of class size in a traditional face-to-face classroom, however, has been contentious, primarily due to concerns about institutional costs, teacher overload and burnout, as well as in achieving student interactions and academic success. Research generally suggests a small class size is preferable to a large class size (e.g., 15 to 20 students). Although there has been some debate in the literature over class size in online courses, the weight of the evidence suggests a class size of 20 to 30 students. The literature review also suggested the optimal class size for blended learning is a small class of 20 to 30 students. This supports the NTDETAS that require driver education courses to consist of a maximum number of 30 students. The general education literature, however, suggests class size may vary depending on course content, requirements, and design as well as on the level of experience of the instructor (i.e., fewer students with novice instructors). It may also be feasible to increase the class size using technology designed to manage more students in a potentially efficient manner, although the effectiveness of this strategy on student performance appears untested.

Virtual Classroom

This term has been used in the literature interchangeably with online learning and typically refers to teaching synchronously in real time. Research suggests effective teaching strategies work equally well in virtual classrooms and in face-to-face classrooms (e.g., instructor-student interaction, promotion of classroom cohesion). The NTDETAS recognizes that virtual, online, synchronously delivered, classrooms are an option for providing the 10 hours of additional instruction or to move from the traditional 30 hours of classroom learning toward a minimum of 45 hours, within a blended program.

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Deliberate Practice and Driver Education and Training

This section of the review focuses on the concept of deliberate practice and the amount of time needed for someone to become an expert, or at least competent, in a complex skill. The difference between deliberate practice and driving experience is also explored. Other topics discussed in this section include:

- whether the number of instructional hours in driver education allocated to classroom and BTW are adequate to produce a competent driver with the necessary skills to drive safely;
- the benefits of intensive (massing) versus traditional (spacing) driver education;
- the importance of overlearning on retention (i.e., practicing a skill even though you no longer improve, which is more characteristic of an intensive learning approach than a traditional spacing one); and
- the effects of block scheduling over traditional, single-session scheduling.

Evidence from the review of the driver education literature pertaining to these issues is summarized and discussed. Insights from studies in the field of education, in general, are shared and considered in relation to the NTDETAS.

Becoming an Expert and Deliberate Practice

Deliberate practice is defined as purposeful, mindful exercises to improve in a skill/domain with repetition and continuous refinement. Activities that are arduous and designed to progressively improve skills over a long time (10 or more years; Ericsson et al., 1993) are a focus. Deliberate practice was initially studied as a method to achieve expertise in motor skills (e.g., sports, music) (Ericsson et al., 1993; Hastings & Rickard, 2015). It typically involves a person practicing by themselves with recurring sessions of one-on-one guidance, support, and feedback from an instructor or coach on extended practice. It also involves intense effort over a prolonged period, and Ericsson et al. estimated a minimum of 10 years of preparation was necessary to achieve expert performance at the highest level that is far superior to the normal level of performance in an ordinary population (i.e., exceptional cognitive, visual, and motor skills) (Hastings & Rickard, 2015). The success of deliberate practice in attaining expertise over such a prolonged period relies on several critical factors, including:

- motivation to improve performance,
- high level of concentration,
- optimal daily duration of effective practice (e.g., to minimize burnout and mental fatigue),
- opportunities and time to identify and correct mistakes,
- high quality repetition/practice,
- rehearsal,
- reflection on the learning experience, and

- highly qualified and effective instructors/coaches/mentors to guide and design practice activities and ensure a high quality of practicing (Ericsson et al., 2007; Hastings & Rickard, 2015).

The literature on deliberate practice and expertise has focused primarily on understanding how someone becomes an expert and the extent to which this is attributed to genetic factors (e.g., innate ability, exceptional talent, heredity) or extended deliberate practice. In a review of an earlier meta-analysis by Macnamara et al. (2014) on this issue, Ericsson and Harwell (2019) observed only 14 percent of the variance in performance was attributable to individual differences in deliberate practice. This result suggested the important influence genetics (i.e., natural, innate, talent) must have in the development of expert performance. Ericsson and Harwell disagreed with this conclusion and took issue with the finding on methodological grounds. They re-analyzed the data with more rigorous conditions applied to the papers included in the original meta-analysis, and reported that deliberate practice, measured as duration of practice, accounted for 29 percent to 61 percent of differences in performance suggesting a far smaller influence of genetic factors. The authors argued the only major exceptions to this may apply with the genetic influences of height and body size, where the activity may benefit from being tall (e.g., basketball), small in body stature (e.g., gymnastics) or large in body stature (e.g., football) to become highly proficient. However, deliberate practice and/or structured practice (i.e., practice in groups) remains an important requirement to achieve this level of performance in an activity.

The authors of the 2014 article, Macnamara, Hambrick, and Oswald, discussed above, challenged Ericsson and Hartwell's perspective on deliberate practice (in Hambrick et al., 2020). They agreed that "expertise is acquired gradually" (a person is not born an expert, although some may be naturally gifted in some areas of performance) and "training can lead to large, even massive, improvements in people's level of expertise" (p. 2). They also observed that Ericsson and colleagues, in their writings over the years, have been inconsistent in their definition of deliberate practice (e.g., is it designed by the teacher, by the student or both; is practice a solo/independent activity or group/team effort). Their primary concern was with conclusions Ericsson and others made regarding the importance of deliberate practice over person-centered attributes (e.g., genes). In other words, they questioned to what extent individual differences in the amount of practice accumulated over many years explained individual differences in expertise.

To address this question, the authors summarized the results from five meta-analysis studies on deliberate practice and expert performance. Based on their analysis, they concluded deliberate practice was an important factor in predicting expert performance but not as important a factor as Ericsson's research suggested. Given the Ericsson and Hambrick papers, there appears to be agreement in the literature about the importance of deliberate practice in developing expertise, but disagreement about the magnitude of the effects of deliberate practice as a "predictor of individual differences" (Hambrick et al., 2020, p. 16) in expert performance. To clarify the issue Hambrick et al. proposed "a multifactorial model of expertise" (p.15), which included:

- "training and other forms of domain-relevant experience,
- developmental factors (e.g., age of starting training),
- ability factors (e.g., aptitudes),

- non-ability factors (e.g., personality traits), and
- background factors (e.g., opportunity to engage in training)" (p. 15).

Expertise requires deliberate practice several hours a day (2 to 4 hours) for 10 to 15 years (Hasting & Rickards, 2015). Or, as Gladwell (2008) estimated based on Ericsson's research, this amounted to about 10,000 hours. Ericsson, however, took issue with Gladwell's portrayal of his research because 10,000 hours was an average, not a "magic number," and Gladwell failed to even mention the concept of deliberate practice in his book (Ericsson, 2014). Regardless of this controversy, this research suggested thousands of hours during at least 10 years of deliberate practice are required to achieve mastery; however, it can be argued that commitment to this number of intense, purposive, challenging practice hours is daunting.

Implications for Driver Education. Driver education and the NTDETAS require students to drive with an instructor for a maximum of 90 minutes a day to complete at least 10 hours. This is in stark contrast to a minimum of 10 years or thousands of hours mentioned previously. However, during driving lessons and the 45 hours in the classroom, instructors and teachers typically provide guidance to students about identifying and understanding the processes and procedures related to driving tasks and practicing driving with their parent/guardian. This guidance would extend the total number of hours of driving practice beyond 10 hours in-vehicle with an instructor. Driver education students may also be provided a logbook to record and structure their driving practice and be encouraged to continue to practice after completion of driver education and passing their road test to drive independently. Regardless, the concept of deliberate practice, however, is only indirectly in the NTDETAS since the standards include BTW with a certified, professional instructor. The NTDETAS, however, do not provide direct guidance regarding the extent to which driver education students should be taught or encouraged by instructors to engage in intense, focused, deliberate (mindful, purposive) practice in any systematic and consistent way.

It would be unrealistic to adopt this deliberate practice concept in a driver education context to develop mastery and produce expert drivers like athletes or musicians. Rather, the purpose of driver education is to produce competent drivers who, at a minimum, have attained the knowledge and skill level to pass the road. This is the minimum standard for safe driving and provides a means to determine if a learner driver has achieved that standard (Mayhew et al., 2016). Of course, driver education and NTDETAS aspire to achieve a much higher standard than just passing the basic road test (i.e., to create safe independent drivers). The critical question is whether 10 hours BTW driving with a qualified instructor and additional related hours of on-road practice under supervision is sufficient time to become a competent and presumably safe driver upon completion of driver education. Yet, the empirical question remains; can deliberate, or even simple, practice improve the level of skills in a relatively short learning/training period to achieve competency in a field/domain?

Becoming Competent Through Rapid Skill Acquisition

According to Hastings and Rickard (2015), citing a paper by Ericsson et al. (2009), only a short period of simple practice is needed for a person to perform everyday activities, such as riding a bicycle. This is because performance plateaus after a certain period as further practice and skill improvement provides scant additional gain. In a book chapter on expert performance, Kaufman (2014) discussed rapid skill acquisition. The author cites Gladwell (2008) and Ericsson et al.

(1993) regarding the 10,000-hour rule to achieve success in different fields of endeavor. Kaufman underscored the value of deliberate practice as a critical means of skill acquisition but took the position that far fewer hours were needed to become competent at a skill rather than the 10,000 hours of deliberate practice to achieve expertise. He contended that 20 hours of "concentrated, intelligent, focused effort" is what is required to sufficiently learn a skill. In this regard, and of some interest to driver education, the Aircraft Owners and Pilots Association indicates that the Federal Aviation Administration requires a minimum of 20 hours flight time, including 15 hours of flight training from an authorized instructor and 5 hours solo flight, to obtain a sport pilot license.

Kaufman identified "4 major steps in rapid skill acquisition:

- Deconstructing a skill into the smallest possible subskills;
- Learning enough about each subskill to be able to practice intelligently and self-correct during practice;
- Removing physical, mental, and emotional barriers that get in the way of practice; and
- Practicing the most important subskills for at least twenty hours."

From Kaufman's perspective, the quality of deliberate practice was critical, not the quantity of practice (i.e., perfect practice makes perfect; R. Hanson, personal communication, 2023). In this regard, the teacher/instructor is an important factor in ensuring deliberate practice is applied effectively. Kaufman also made important distinctions between skill acquisition and training relevant to driver education. First, he observed that acquiring a new skill requires practice and learning enhances that practice, but it did not replace the critical need for it. The example he provided was related to learning a language. Someone can learn a language in high school with a high passing grade at the end of the course but unless they practice it, they would gradually lose their language skills. Second, the author viewed training as a technique to improve a skill that has already been acquired through repetition, "it's what happens after you've acquired a basic skill if you want to keep improving."

Kaufman also described the "three-stage model of skill acquisition"; a model that may have some application for driver education, especially since the same model has been described by Evans (1991) in relation to driving.

- "Cognitive (Early) Stage – understanding what you're trying to do, researching, thinking about the process, and breaking the skill into manageable parts.
- Associative (Intermediate) Stage – practicing the task, noticing environmental feedback, and adjusting your approach based on that feedback.
- Autonomous (Late) Stage – performing the skill effectively and efficiently without thinking about it or paying unnecessary attention to the process."

Finally, Kaufman also described several principles of skill acquisition related to deliberate practice that may also be relevant to driver education.

- "Focus your energy on one skill at a time.
- Define your target performance level.
- Deconstruct the skill into subskills.

- Obtain critical tools.
- Eliminate barriers to practice.
- Make dedicated time for practice.
- Create fast feedback loops.
- Practice by the clock in short bursts"

This process and principles are very similar to spiral learning theories and strategies (Bruner, 1960; Johnston, 2012), which involve presenting key concepts and subject matter repeatedly and increasing the complexity of the topic with each revisit, or in different applications. The teaching strategy is based on moving from simple to complex ideas, with new information building on existing information. Strategies for rapid skill acquisition are also shared by Hollins (2019), who identified four stages of learning and developing competence.

- Unconscious incompetence – you don't know what you don't know.
- Conscious incompetence – you know what you don't know but can't do anything about it.
- Conscious competence – you know what you need to know and now you can do it.
- Unconscious competence – you know what you know and can do it without even thinking about it.

In a driver education context, this suggests young teens enrolling in a program are at the stage of unconscious incompetence knowing little, if anything, about the myriad of tasks and skills needed to drive safely. By the end of the program, they should have achieved the stage of conscious competence, at least regarding basic motor skills and road craft. Using basic and higher-order skills taught to them in driver education, combined with the accumulation of on-road driving experience, they gradually enter the stage of unconscious competence. Hollins (2019) discusses deliberate practice as well as other strategies to enhance learning (e.g., interleaved practice, alternate between one or more skill at a time).

In the Kaufman book (2014), the author described in detail how he applied deliberate practice and the principles/models he identified in acquiring several new skills in twenty hours or less and 90 minutes or less of practice per day for each skill. These skills included, for example, yoga, touch typing, and a musical instrument.

Kaufman clearly advanced several insights on deliberate practice and rapid skill acquisition, based to some extent on the literature (e.g., references to Ericsson's published work and others), that appear to have relevance for driver education. Some caution, however, is warranted in giving his book chapter too much weight because the book primarily focused on his own experiences in rapid skill acquisition with some reference to scientific evidence in support of his perspectives. Our literature search conducted for the current white paper did not identify any peer-reviewed journal articles under his name. However, this perspective on rapid skill acquisition through 20 hours of purposive, intense deliberate practice provides food for thought, especially given that other authors have discussed rapid skill acquisition (e.g., Hollins, 2019), and the Federal Aviation Administration requires a minimum of 20 hours flight time to obtain a sport pilot license. Taken together, this suggests driver education may have hit its "sweet spot" with 10 hours of BTW driving and instructor-guided activities (homework; feedback to parents on student progress and remedial needs) and driving practice under supervision of a parent/guardian. Under these conditions, driver education may be a potentially effective means of teaching a beginner to become a competent and safe driver. The critical issue is the extent to which driver education applies deliberate, purposive practice to skill acquisition in driving over the relatively few hours available for instruction and driving practice. This may be particularly problematic because teachers and instructors in driver education typically focus on an hourly standard rather than purposive practice during lessons (R. Hanson, personal communication, 2023).

Driving Experience and Deliberate Practice

A related and important issue to the above discussion is the extent to which acquiring driving experience truly constitutes deliberate practice. Gaining driving experience is not purposive (i.e., for the explicit purpose of improvement in a set of driving skills); rather, driver experience is a by-product of the need for mobility. Driving experience is also probabilistic learning in which learning comes from individual experiences as well as by imitation (i.e., being influenced by the behaviors of other people such as parents, peers, and other drivers) (Boboshi AB., n.d.).

Ericsson would define this type of practice as naïve practice and suboptimal to deliberate practice. A comparison is to a recreational golfer who frequently plays golf and incrementally improves their game but plateaus at some point without much or any further improvement. As Ericsson et al. (2007) observed “not all practice makes perfect” (p.3). The accumulation of driving experience differs from deliberate practice because it is largely unstructured and develops over time with exposure to diverse driving situations, including everyday driving activities or diverse driving situations that may impose unexpected or risky on-the-road driving situations. And drivers in their initial years of driving are not particularly motivated to improve specific aspects of their driving performance. It is important to keep in mind that even though gaining driving experience may be characterized as a naïve form of practice and suboptimal to deliberate practice, driving skills improve with driving experience and this has safety benefits (Mayhew et al., 2016). Indeed, the road safety literature is clear that gaining driving experience reduces the risk of collision (Mayhew & Simpson, 1995; Whelan et al., 2004; Berg, 2006; Shinar, 2007; de Craen, 2010; Helman et al., 2010; Kinnear et al., 2017; Foss et al., 2011; Chapman et al., 2014; Curry et al., 2015; Mayhew et al., 2016; Mitchell et al., 2015; Newnam et al., 2016; Senserrick & Kinnear, 2017). Probabilistic learning and learning by imitation can also have negative consequences. Experienced drivers are unlikely to have achieved expert status over decades of driving, in part, because bad habits are also acquired with driving experience. Typically, there is no corrective mechanism to recognize these safe driving errors/mistakes/skill deficiencies and improve them (Ericsson et al., 2007). Further thought and efforts are required to identify effective educational/training or corrective methods that could be applied to deal more effectively with driving deficiencies that develop in experienced drivers.

Lifelong Learning and Deliberate Practice

The NTDETAS promote the notion of lifelong learning and driver education as an important component in that process but are absent guidance about how to foster and encourage continual deliberate practice. This may not be an expected role for the NTDETAS but rather be undertaken as supplemental activities to the NTDETAS (e.g., a white paper on Best Practices for Lifelong Learning). This could also take the form of post-licensing tests in which drivers prepare in advance of being tested, or periodic booster or refresher courses after driver education during the first few years of independent driving when crash risk is highest among teen drivers. This may require a concerted effort to convince teen drivers to take an active role in deliberate practice, not just driving, after they pass the road test. This is especially the case because some teens who have driven independently may feel they are expert drivers so there is no need for them to practice critical and higher-order driving skills. The question is whether this should be the responsibility of driver education and the NTDETAS, alone, or in partnership with the Department of Motor Vehicles (or its equivalent), or some other traffic safety organization or a collaborative effort of like-minded stakeholders concerned about teen driver safety.

Deliberate practice is critical to producing a competent driver. This will rest on the quality of instruction from driver education teachers and the professional development of instructors to ensure they are up-to-date and informed about applying deliberate practice techniques and other educational/training methods to enhance learning (e.g., spiral learning theories and strategies).

Instructional Hours

Traditional or standard driver education courses are comprised of several delivery approaches: classroom (30 hours); BTW (6 hours), hands-on training; and in-vehicle observation as a passenger (6 hours) (Mayhew et al., 2014). The 30/6 model can be traced back to the First National Conference on High School Driver Education, held in 1949, which recommended a minimum of 30 hours of classroom and 6 hours behind-the-wheel, excluding observation time (Stack, 1966). Although this early paper by Stack on the *History of Driver Education* established when and where this model was recommended, it did not discuss the reasons these specific hours of instruction were selected. The High-School Driver Education: Policies and Recommendations paper prepared by the National Conference on High-School Driver Education (National Commission on Safety Education,1950) also does not address reasons for this recommendation (D. Ritzel, personal communication, 2023).

The literature search, however, did identify one source that provides at least a partial answer. The NTSB convened a public forum on driver education in 2003. In the proceedings of this public forum, James Nichols, a traffic safety specialist, and former NHTSA employee, was cited as informing NTSB that this time-based model emerged from consideration and balancing of the time needed and available to teach driver education in a high school setting, and the time funded (NTSB, 2005). In other words, as observed by Williams et al. (2009), the 30/6 model was structured to work in a high school setting. In this regard, Kline (2019), in an article on the Changing World of Driver Education, mentioned that “Since the school terms were 36 weeks in length, the once-a-week program fell into the school year easiest in this format. It has been a great struggle throughout our short history to have school systems involved in any more hours of instruction than 30 and 6” (p.2).

The literature search did not identify any other source documenting further reasons for adopting the 30/6 model. Albeit speculative, it is likely that attendees and leadership at the national conference were striving to achieve some degree of uniformity over a diversity of practices in the delivery of driver education across the United States. The 30/6 split was likely the standard practice or norm at that time, so this model was recommended as “best practice.” The model was likely viewed as a compromise constituting an acceptable and achievable approach, and an affordable means for delivering driver education in high schools across the country. This is still the mentality in driver education today (A. Urie, personal communication, 2023).

The recommendations on instructional hours from the 1949 conference appears to have had a major influence on the delivery of driver education programs across the United States. As noted by Stack (1966), in the 1940s, only a few high schools offered the full program. By the mid-60s, most high schools (68%) offered a minimum of 30 hours in classroom and 6 hours of BTW driving or laboratory instruction (Stack, 1966).

The NTSB, based on its 2003 investigation and public hearing on driver education, concluded that "the 56-year-old formula of 30 hours of classroom training followed sequentially by 6 hours of BTW training was determined arbitrarily and is probably inadequate to teach teenagers the skills necessary to drive safely on today's roadways" (NTSB, 2005, p. *x*). Several more recent studies of driver education similarly concluded that although this time-based model was effective in preparing students to pass the basic road test, it was unrealistic to expect that 30 hours in classroom, 6 hours BTW and 6 hours in observation would transform an inexperienced, immature, novice learner into an experienced, mature, adult driver with significantly lower crash risk (Williams et al., 2009; Lonero & Mayhew, 2010; Thomas et al., 2012). The reasons traditional driver education may fall short of achieving its primary safety objectives have been outlined by Williams et al. (2009):

> "The courses generally are of short duration, and most time must be spent teaching basic vehicle handling skills. This leaves less time to try to teach safe driving skills. The audience for driver education may also be relatively unmotivated regarding safety, the primary motivation being to learn enough to get a driver's license. Probably the biggest impediment to driver education effectiveness involves the inherent difficulties in affecting lifestyle and developmental factors: the attitudes, motivations, peer influences, and cognitive and decision-making skills that are so influential in shaping driving styles and crash involvement.
>
> The situation for driver education is really no different than that of short-term school-based courses attempting to influence the use of alcohol, other drugs, or tobacco. These health education programs have also largely failed, for many of the same reasons driver education courses have." (p.11).

Williams provides a unique and informative perspective on the challenges facing driver education and how these are akin to challenges facing substance abuse, school-based health-courses. It is, however, important to underscore that although much of driver education focuses on teaching basic vehicle handling skills (e.g., steering and braking a vehicle), these are the foundation of "safe" driving and are the driving skills that must be mastered before higher-order driving skills can be taught or learned.

In recognition that the traditional 30/6/6 model of driver education may be limited in its ability to effectively teach critical safe driving skills and to improve their driver education curriculum, the American Driver and Traffic Safety Education Association (ADTSEA), in 2006 recommended 45 hours of classroom and 8 hours of BTW driving instruction (Chaudhary, 2011). As observed by Williams et al. (2009), this increase in instructional hours "represents the latest thinking on what should be taught in a driver education course and how it should be taught" (p. 15). ADTSEA was a founding member of the working group that developed the NTDETAS, and in the first edition of these standards, instructional hours were increased from 30 to 45 hours of classroom. Although ADSTEA recommended 8 hours of BTW instead of the traditional 6 hours, the working group decided on 10 hours in the standards, in part because working group members from private driving schools felt more emphasis should be placed on in-vehicle training.

Although moving from 6 to 10 hours of BTW training represented a major 67 percent increase in practical lessons, it still fell far short of practices in some European countries where professional driving lessons have historically been given even more emphasis than in the United States. In Belgium in the 1990s, for example, there was a requirement for a minimum of 20 hours of professional training, twice as many hours as recommended in the NTDETAS. France still requires 20 hours of driver training in a driving school (Hutchins, 2008), and a few European countries (e.g., Sweden, Austria) required multi-phased training in two parts; 9-hour basic training and then 20 additional hours of more advanced training that included intensive braking (Kiss, 2016).

Although practical driving lessons are not mandatory in the United Kingdom, it was estimated that novices took an average of 45 hours of BTW training to achieve the driving skills necessary to pass the road test (https://toptests.co.uk/how-long-does-it-take-to-learn-how-to-drive/), which was more rigorous and demanding than road tests typically administered in U.S. States. In a review of current driving training and testing practices in Europe for the European Commission, Helman et al. (2017) observed that training practices across Europe differed extensively, including variations of formal training (i.e., driving lessons from a qualified driving instructor) and informal learning (i.e., accompanied driving or what is called supervised driving in the United States). Helman et al. found, however, that formal training was the only way learners can prepare for the practical test in most Member States, including, for example, Denmark, Germany, the Netherlands, the Czech Republic, and Greece.

The new 45/10/10 model in the NTDETAS emerged from a working group established by NHTSA, including ADTSEA, the Driving Schools Association of the Americas and other national traffic safety agencies, and expert opinion as to what was achievable since little, or no research was available to support these important modifications in the delivery hours of driver education. At issue is whether there is scientific evidence, or other compelling reasons, beyond the argument that "more education/training is better" to support the increase to 45 hours of classroom and 10 hours BTW.

Evidence to Support the 45/10/10 Model

The issue of the optimal hours, or at least a different mix of teaching components, was specifically tested in the Dekalb County evaluation of driver education over three decades ago (1987). This was one of the most rigorous and controversial studies of the safety effects of driver education, often cited in the literature as resulting in the demise of driver education across the United States, especially in the public high school system. The project involved approximately 16,000 students being randomly assigned to one of three groups: the Safe Performance Curriculum (70-hour course, simulation, range, and on-street training); the standard or traditional course (modified curriculum including four-phase instruction); and a control group who received no formal driver education. As described by Lonero and Mayhew (2010; p. 20), the Safe Performance Curriculum involved formal instruction using several delivery approaches: 32 hours of classroom, 16 hours of simulation, 16 hours of off-road range driving, 3 hours of collision evasion, and 3.3 hours of on-road, BTW driving, including 20 minutes at night.

Although there has been considerable controversy, several analyses of the data from the study, and different interpretations of the study results (see Mayhew et al., 1996; 1998), the findings over many studies were equivocal and failed to provide consistent evidence of the beneficial effects of formal instruction. A conclusion that can be drawn from this experimental evaluation is that increasing the number of driving practice hours with simulation and range instruction had no positive safety effects. This investigation, however, did not provide a direct test of the safety effects of more classroom hours or more on-road BTW hours for two reasons. Classroom hours were almost equivalent between the comparison groups (32 versus 30 hours for the enhanced and traditional courses, respectively). Furthermore, BTW hours instead decreased, not increased, from the traditional 6 hours to only 3.3 hours on the road in the Safe Performance Curriculum.

Implications for Driver Education

In the absence of scientific evidence to support an increase in hours of instruction and recognizing that driver education has been largely successful in preparing students to drive and achieve at least the minimal skills to pass the road test, a few researchers have argued there is no need to modify the course (Thomas et al., 2012). Peck (2011) has gone even further in stating:

> "There is no evidence or reason to believe that merely lengthening the number of hours on the road will increase effectiveness. Programs directed toward attitude change and risk taking better address the underlying cause of the elevated crash risk of young drivers, but these behaviors are notoriously resistant to modification in young people." (p. 63).

> "This raises the difficult question of how to change the attitudinal and maturational factors underlying risky driving behavior through classroom and on-the-road training. It is difficult to see how simply requiring more hours of on-the-road training addresses the underlying problem." (p. 70).

Peck appeared to be suggesting it was more important to improve the focus and quality rather than the quantity of driver education, although this will be difficult to address given the critical person-centered risk factors (e.g., immaturity, susceptibility to peer pressure to take driving risks, alcohol- and drug-impaired driving, poor risk perception) that account for teen driver crashes. As suggested by Thomas et al., an important focus in driver education should continue to be on teaching inexperienced beginners how to operate a vehicle and preparing them for the road test and, in this regard, driver education is an important gateway to independent driving and mobility.

An increase in the number of hours from the 30/6/6 model to 45/10/10 formula, which would be in line with a deliberate practice approach, specifically provides an opportunity for driver education to better address the critical risk factors associated with teen driver crashes. Given the complex nature of these underlying factors, as Peck argued, it may be difficult to modify them but, and importantly, not impossible with the appropriate blend of new content, teaching strategies, and delivery modes, including a better application of deliberate practice. Rather than being paralyzed by the difficulties and the reasons more hours of education and training will not work, the focus should be on how to make it work. Teacher training/preparation and professional development are a very important part of this solution. This may require breaking down barriers and overcoming teacher/instructor resistance to change that challenges traditional teaching methods and strategies in the field of driver education.

In this regard, the GDE matrix discussed in the previous section provides insights into how to broaden the scope of driver education and training, including addressing higher-order risk factors, such as risk-taking and lifestyle (Hatakka et al., 2002). Also, the NTDETAS not only increased instructional hours for each delivery component of driver education, but they also recommend:

- an additional 10 hours of flexible instruction using a variety of learning approaches such as, but not limited to observation, behind-the-wheel, range, simulation, classroom/theory (e.g., traditional, online, virtual, hybrid),
- online independent student learning (e.g., hazard anticipation training), and
- virtual/augmented reality.

The challenge is to develop or adopt safety-critical new content and apply more effective delivery modes that can be blended into the core driver education program as substitutes or supplements to subject matter to address key, higher-order, risk factors more effectively. In this regard, and as an example, research has demonstrated that young drivers have poorer hazard perception skills compared to experienced drivers, and deficiencies in hazard anticipation, prediction, mitigation, and maintenance skills contribute to their elevated crash risk (Mayhew et al. under review). NHTSA's *Countermeasures That Work* (Kirley, et al., 2023) now includes hazard perception as a two-star-rated countermeasure, meaning that it currently has limited evaluation evidence, but if implemented well, could prove to be effective in changing behavior. According to Horswill et al. (2021), "hazard perception training is typically defined as a driver's ability to anticipate situations that may lead to collision and has been conceptualized as a driver's situation awareness of crash-relevant aspects of the traffic environment" (p.2). There are several hazard perception models (e.g., Risk Awareness and Perception Training [RAPT], Pollatsek et al., 2006; Pradhan et al., 2009), SAFE-T (Yamani et al., 2016), Accelerated Curriculum to Create Effective Learning (ACCEL) (Fisher et al., 2017). Evaluation studies of these computer-based/online independent student learning or online hazard perception training programs have shown improvements in these critical skills. In addition, although crash-based studies are scarce, there is at least some evidence that these types of training programs reduce teen driver crashes (Mayhew et al., in press). An online independent student learning or online hazard perception training program could be integrated as a substitute for ineffective and/or dated, unnecessary content, or as a supplement to what is already being taught (e.g., as homework). On a positive note, hazard perception training is already integrated into the AAA's How to Drive curriculum (n.d.) both in classroom and online. The NTDETAS with the increased instructional hours has the capacity to include potentially effective new content and blended learning activities to address the safety needs of teen drivers more adequately.

Another reason for the increased hours for driver education in the NTDETAS is to address emerging issues related, for example, to the rapid growth of in-vehicle safety technologies (advanced driver assisted) and the accelerated move towards automation and electric vehicles over the past few decades (Casner & Hutchins, 2019). This speaks to the need to teach new drivers in driver education settings about emerging vehicle safety features and vehicle automation; technological advances that will affect their driving and safety. This critical need is recognized in the AAA's How to Drive curriculum (n.d.) with a chapter devoted to new vehicle technologies and how to use them, not misuse them (B. Van Tassel, personal communication 2023). Also, smart phone use while driving has become prevalent among teenagers and distracted driving remains a critical risk factor contributing to their crashes (Gershon et al., 2017; Mayhew et el., 2013; Stavrinos et al., 2015). Contemporary driver education content and training are needed to adequately address issues related to the perils of distractions, especially by smart phone use when driving and in-vehicle navigation systems. As an example, the AAA's How to Drive curriculum (n.d.) already covers these key topics (B. Van Tassel, personal communication, 2023). As the vehicle fleet turns over with time and replenishes older vehicles with newer ones that are more automated and technologically advanced, these emerging issues will become increasingly critical to address in driver education.

Intensive Versus Traditional Delivery of Driver Education

Driver education can be taught over a few days/weeks (so-called crash courses) or spread out over several weeks or months. The traditional driver education approach, which is the norm at least in the United States, is to deliver driver education over a relatively long period, for example, a semester or four months for a driver education program delivered in high school. The NTDETAS establishes that classroom education be distributed over a period of 30 days or more.

The second national conference on driver education held in 1953 addressed the issue of short courses and strongly rejected the approach. Nonetheless, over the decades, courses of short duration, even just a few hours, have proliferated across the United States. For example, North Dakota and South Dakota teach their courses in 2 weeks during the summer, 30 hours of classroom first and then 6 hours of driving over the second week (R. Hanson, personal communication, 2023).

Hamilton (2012) has questioned the ability of short duration courses to markedly improve driving skills over longer duration courses. The search of the driver education literature identified only two studies comparing the efficacy of these two delivery approaches. Vlakveld (2005), in a study conducted in the Netherlands, reported that short, intensive driving courses were more effective than traditional courses as students in short courses needed fewer hours of practice with a driving instructor to pass the driving test. On average, an intensive driving course and traditional driver education took 34.9 and 43.1 hours of BTW instruction, respectively, to pass the driving test. Another Netherlands study produced conflicting results with Vlakveld's earlier findings and favored traditional driver training over short duration courses. De Craen and Vlakveld (2013), in a study examining the effects of intensive driving courses compared to traditional driver training, found both short course drivers and those traditionally trained had almost the same number of training hours. What differed between the two groups was the spacing of these hours. Student outcomes in their study included driving test results and safe driving in the first two years after passing their road test.

In contrast to Vlakveld's earlier study, results in which drivers in short duration courses needed fewer hours of training to pass the drive test, de Craen and Vlakveld (2013) reported no difference between short course students and those traditionally trained in the total number of hours needed before passing their test. Their results also showed no differences in the number of attempts to pass the driving test between the two groups. Drivers in the short, intensive course reported significantly more crashes than drivers completing traditional driver training over the first two years of driving. The authors observed the differences in reported crashes were due to the spacing of the driver training (i.e., spacing effect) given that there was no difference in the number of training hours or content of the training. Since the study did not adopt an experimental design with random assignment of subjects to the short or longer duration training courses, the authors considered biasing from self-selection by examining available demographics (e.g., gender and age) and other factors (e.g., frequency of car use, weekend trips, trip purpose, driving with passengers, driving impaired, nighttime driving, speeding, seatbelt use) that might have influenced crash occurrences. There were no significant differences between the two groups with respect to these factors, so they concluded that even though there was no evidence of a self-selection bias, other factors might have still accounted for the difference in the reported number of incidents.

The limited scientific evidence in the driver education field suggests traditional driver education in which students are taught over a long period of time produces better student outcomes than intensive driver training courses in which learning is condensed over a short period of time (Vlakveld, 2006; de Craen & Vlakveld, 2013). A review of the general education literature on the distribution of learning and the duration of spacing gaps that separate repeated exposure to information supports this conclusion. This research dates to 1885 and early studies, which demonstrated the benefits of spaced or distributed practice over mass or continuous practice (i.e., cramming) (Son & Simon 2012). Since then, research evidence on the benefits of spacing over intensive learning has been relatively consistent, especially for complex tasks that require retention over a long period of time. Teacher interaction and feedback becomes important, however, to ensure that students do not wait until the due date and end of the assignment to cram the material to finish in the last few days – students do not necessarily do well with self-paced learning (A. Urie, personal communication, 2023).

The benefits of spacing have been documented in the laboratory and in classrooms for both cognitive learning (e.g., word recall, math problem) and coordinated motor learning tasks or motor skills (e.g., typewriting, archery, microsurgical skills) (Son & Simon, 2012). The practical application of spacing in real-world classrooms is important because it confirms positive results on spacing effects that emerged from laboratory studies. Kapler et al. (2015), for example, examined the effects of spacing in an educational setting with undergraduate students. Participants received a lecture on natural science material, reviewed the material either one day or 8 days afterwards and completed a final test on the material 5 weeks after their review. Results demonstrated a spacing effect as students reviewing the material 8 days after the lecture had better test scores than those reviewing the material after only 1 day. Based on these results, the authors concluded that spacing was a robust and effective learning approach that should be applied in the classroom. In fact, spacing has been shown to improve recall of information learned in the classroom when tested even 9 months after the final session (Rohrer & Pashler, 2010). These are interesting findings mostly based on undergraduate students, but it is not clear if results would apply to younger teens (e.g., 14 and 15 years old in driver education) who are less cognitively developed (R. Hanson, personal communication, 2023).

The literature also distinguished between implicit and explicit learning processes. Implicit learning involves gaining knowledge without conscious awareness of learning whereas explicit learning is acquired with the use of overt strategies. Son and Simon (2012) suggested spacing effects were more pronounced for explicit processes, involving the use of readily apparent strategies such as verbal or cognitive learning. They predicted that since motor skills involved implicit learning, the benefits of spacing may be less apparent for motor learning tasks (Anderson, 2000) and this may require "a somewhat more nuanced account of and recommendations about spacing in motor and procedural learning scenarios" (p. 383). Authors, Son and Simon (2012) discussed the literature on motor skills that, as mentioned previously, also demonstrated the benefits of spacing and they underscored those positive spacing effects on learning motor skills were "long established" (p. 383). They also observed some studies that demonstrated with experiential learning and motor tasks (e.g., practice on a new smartphone) massing or continuous practice resulted in faster performance than spaced practice. They concluded "spacing benefits are not always obvious when it comes to actions." (p. 384).

Spaced learning has also been shown to promote generalization, that is applying a concept or cognitive skill learned previously to a new context (Vlach & Sandhofer, 2012). This has been demonstrated with respect to both simple and complex generalizations. Vlach and Sandhofer speculated that with spacing, students may forget much of the information but remember relevant features and the underlying structure that they can use to generalize in new situations. This has important implications for driver education because it suggests spaced learning may improve the student's ability to critically problem solve in the driving task by generalizing previous driving experiences and learned skills to new situations.

A positive spacing effect has also been demonstrated in studies with adult learners and younger participants, including middle-school children and teenagers (Carpenter et al., 2012). As observed by Son and Simon, spaced study, generally, resulted in better performance for long-term retention than uninterrupted, mass study, so they concluded "spacing study is the optimal strategy" (p. 392). Similar conclusions have been reached by Rohrer (2015; p. 640) who underscored that the best method to achieve long-term learning or what the author referred to as "durable learning" was when subject matter was distributed or spaced over longer not shorter time (i.e., study that is spaced over a month is better than spacing the subject matter over a few days or a week).

Optimal Spacing Gap

A critical question is determining the appropriate spacing so the time interval between learning sessions is not too short or too long for spacing effects to work best on memory or skill development (Carpenter et al., 2012; Son & Simon 2012). The literature generally suggests longer spacing gaps are better than shorter retention ones (Carpenter et al., 2012). However, the benefits of a spacing effect may be eroded if the time interval is too long because students may forget what they have learned. Even if students have forgotten much of the information, however, a brief review or a test requiring students to go over the subject matter again, will result in them acquiring the information faster than when they learned it initially. A few studies reviewed by Carpenter et al. (2012) attempted to identify an optimal spacing gap. Based on their review, Carpenter et al. concluded "there is no 'one-size-fits-all' approach" and much depends on "when they expect to need the information" (p. 374). Short-term retention of information may benefit from shorter spacing gaps whereas memory retention for longer periods may require spacing gaps of several weeks or months. And they observed that "for lifelong retention of knowledge, spacing gaps of years may well be optimal" (p. 374). Achieving the optimal time interval for spacing is critical because of the concern that as a teaching method, spacing sessions may be relatively time inefficient. This may be why, in practice in educational institutions, spacing gaps between sessions over a significant time is not always a popular learning strategy (Son & Simon, 2012). It is also possible that reluctance to adopt spacing over time is because this teaching method may be costly for schools and providers. Qualified, well-trained educators in this approach should be able to identify appropriate spacing gaps that will enhance learning (Hattie, 2003)

Implications for Driver Education

The NTDETAS apply a distributed or spaced learning approach requiring "that the acquisition of knowledge and skills is spread over a longer period of days and weeks" (p. 44). The NTDETAS also call for spacing from classroom sessions to sessions outside of the classroom in the form of homework and driving assignments that speaks to the generalization of the subject material and tasks being taught. This integration of subject material and spacing provide students with real-world driving benefits and the opportunity to reinforce their learning through practice and repetition. What is not known, however, is whether, in practice, optimal spacing gaps have been established between learning sessions in, and out, of the driver education classroom. The extent to which learners are being re-exposed effectively (for example, by repetition, summary reviews and/or tests; Brenner 1960) to concepts and skills taught in previous lessons is also not known. It will be important in the future to ensure driver education maximizes the benefits of distributed/spaced learning.

Overlearning and Driver Education

The general education literature has also focused on the issue of overlearning, which relates to the notion of "laboring in vain" (Son & Simon, 2012, p. 384). As Son and Simon observed in their review of this literature, practicing a motor learning task over two hours resulted in diminished or no increases in learning and "we simply get burnt out" (p. 384). This finding has relevance for driver education and suggests that longer BTW sessions may have counterproductive learning effects.

Overlearning is more likely to occur when "cramming" in short, intensive courses and may have only short-term positive effects on retention. In an early meta-analysis of the literature on overlearning, Driskell et al. (1992) noted the effects of overlearning on retention, at least for the short-term, were significant for both physical and cognitive tasks. In the case of verbal or cognitive learning, studies have shown increases in the number of cognitive tasks in a single session (e.g., repeatedly practicing nine versus three math exercises of the same type in one class session) may improve student test performance in the short-term (e.g., a test immediately following the session), but retention of the information is not long-lasting. Rohrer et al. (2015), for example, examined the effects of overlearning on long-term retention of geographic facts and word definitions. Authors reported the test scores of over learners were better than non-over learners one week after the session, but this difference dissipated over time. Other studies have also demonstrated the short-term benefits of overlearning decline as the time between practice and test increases, or there is no benefit of additional (overlearned) versus fewer (mastered) practice problems for retention of information/concepts (see Rohrer & Taylor, 2006). In examining overlearning in math problems, which involves more abstract learning than is the case with learning facts (rote memory), Rohrer and Taylor observed that "a small amount of overlearning may be useful if overlearning is strictly defined as any practice beyond one correct problem" (p. 7). Practicing beyond that point would result in diminishing returns and no further increases in learning or retention, especially over the longer term.

Taken together, the literature suggests overlearning may have short-term benefits, which would be useful, for example, in preparation to pass an exam at, or shortly after, cognitive or motor tasks have been overlearned, but it has no benefit for retaining knowledge and skills over the long-term. The NTDETAS do not currently address the issue of overlearning, which might be a useful strategy to assist novices, for example, in passing the DMV knowledge and road tests.

They do, however, promote driver education as the foundation for students to continue a lifelong learning process. If the objective of driver education is to produce safer drivers, overlearning may be beneficial in the short-term but may not help novices' longer-term retention of critical safe driving knowledge and skills.

The ADTSEA Novice Teen Driver Education Curriculum Standards, which are part of the NTDETAS, call for 22.5 sessions of 120-minute training segments (a total of 45-hour program). This assumes the content in each of the 22.5 sessions is equivalent in terms of study duration (i.e., the amount of time needed to learn the material). It is possible that some of these sessions, because of the type and amount of content taught, result in overlearning to fill the 120-minute time block. For each of the 22.5 sessions, students need to successfully learn the material and skills taught but not overlearn them because overlearning might be detrimental to long-term retention. An important caveat is that Rohrer et al. (2005) also observed the benefits of overlearning on long-term retention may vary for different types of tasks. Hence, the extent to which overlearning is appropriate in some cognitive and skill tasks but not others is an empirical question. Driskell et al. (1992) observed that overlearning effects are influenced by not only the kind of task but also the amount of overlearning and the length of the retention period.

The extent to which overlearning occurs in practice in driver education courses across the United States is not known. In this regard, a NHTSA-funded study by Chaudhary et al. (2011) on driver education practices in several States in relation to ADTSEA standards (e.g., 45 hours of classroom) revealed some similarities across courses, for example, in the subjects taught and overall course duration, but also some variability, especially in relation to the required hours of BTW instruction. Most courses examined still employed traditional instruction hours or fewer driving hours with an instructor rather than those recommended by ADTSEA (the average was 4.6 hours BTW and not the 8 hours recommended by ADTSEA, at that time, or even the 6 hours of traditional driver education). This study did not address issues related to overlearning and provides no insight on driver education practices in that regard. It is also possible that students decide to overlearn material (e.g., in the driver handbook) and/or driving skills needed to pass the road test outside of driver education but the extent to which this happens is not known. Also, it is not known whether overlearning might have longer-term benefits for specific driving tasks (e.g., braking skills, hazard perception abilities) and as such, the issue of overlearning in relation to driver education an outstanding issue.

Block Scheduling and Driver Education

An issue in the general education literature that has relevance for driver education is the practice of block scheduling (e.g., 90-minute class periods) compared to traditional scheduling (e.g., single 45- or 60-minute class period). Block scheduling has been used in high schools in the United States for several decades (Gruber & Onwuegbuzie, 2001). It was a learning approach recommended in the mid-1980s by the U.S. Department of Education as a "new standard" to provide more time for learning and, thereby, enhance student performance (Mizhquiri, 2019). Since block scheduling resulted in fewer classes, a common view was that students should be less overwhelmed with the substantial demands, variety of rules, and fragmented curricula they faced with more classes in a traditional scheduling environment. It was also felt that block scheduling was a more effective use of school time than the traditional single-session approach (Gruber & Onwuegbuzie, 2001). By the 1990s these authors referenced studies estimating 40 percent to 50 percent of high schools in the United States had implemented some form of block scheduling (p. 33).

Studies examining the effects of block versus traditional class scheduling have produced mixed results (Gullat, 2006; Gruber & Onwuegbuzie, 2001). For example, in a study by Gruber and Onwuegbuzie, results varied by type of subject with no statistically significant difference between block and traditional scheduling for Writing on a high school graduation test, but better performance of traditional scheduling on the test for subjects such as Language Arts, Mathematics, and Science. Considering such findings, some high schools stopped using block scheduling and returned to more traditional, single-session scheduling (Gullat, 2006).

Although the literature does not provide solid and consistent evidence in support of block scheduling, there are circumstances in which this scheduling approach appears to work. Labak et al. (2020), for example, noted the positive effects of block scheduling depended on high school grade level. Authors reported the performance of third-year high school biology students, but not fourth-year students improved with block-scheduled classes, and first-[t] and second-year high school students benefited more from single-scheduled classes. The effects of block scheduling or longer class periods appeared to be variable and influenced by such factors as student age (i.e., grade) and knowledge level. With respect to knowledge, Labak et al. (2020) provided this plausible explanation.

> "In 1st and 2nd grade, the anticipated concepts required many facts to be remembered and correctly connected to the students' prior knowledge. In such circumstances, and according to our results, single-scheduled classes might provide better memory consolidation through regular repetition. In 3rd grade, students achieved better results when they learned within block scheduling, while the 4th grade students showed the same results regardless of the scheduling (single or block). This indicates that by growing the prior knowledge (i.e., by building a more complicated knowledge network) during schooling, the degree of teacher's assistance and leadership in conceptual linking may be dropping (that is likely to occur in 4th grade within this study)." (p. 14).

Based on these findings, Labak et al. recommended mixing block and traditional scheduling to maximize the effects of the two scheduling approaches based on, for example, high school grade and student age. This has also been an alternative scheduling approach suggested by Childers and Ireland (2005). There is at least some evidence that a tri-schedule approach that combines block, traditional and hybrid, was effective in improving most students' satisfaction and grade point average (Gruber & Onwuegbuzie, 2001). These authors also observed that research suggested a key factor in the success of block scheduling is instructor preparation and training. Hence, future efforts should focus on professional development in the adoption of block scheduling. Simply introducing block scheduling does not improve the quality of instructors or their teaching methods and habits established over years in the classroom (Gullat, 2006). Some research reported by Gullat (2006), for example, showed instructors do not change their teaching methods to adapt to the longer periods of time, and many continued to rely on a lecture format and the same instructional strategies they had used in traditional sessions. Not surprisingly, Gullat, like Gruber and Onwuegbuzie, recommended instructor professional development as a strategy to ensure block scheduling works. In this context, how instructional time in driver education is being used is not well understood. Gruber and Onwuegbuzie also suggested block scheduling may be effective in one school system but not another. Those factors that best support the success of block versus traditional, single-session scheduling in a driver education setting, however, are not well-known. This is another clear example that one-size does not fit all.

In a recent literature review on the effects of block and traditional scheduling, Mizhquiri (2019) also reported mixed evidence with no consistent effects of block versus single course scheduling on high school student performance. Students and teachers, however, generally expressed positive perspectives towards block scheduling, which was a teaching approach, for example, that provided more opportunities for in-class interactions, more time to ask/answer questions, less homework, and not as much focus on a lecture format. Block scheduling also had other benefits such as better attendance, lower dropout rate, and fewer disciplinary actions (Gruber & Onwuegbuzie, 2001). Weaknesses of block scheduling have also been noted and these include student boredom and difficulty for a student missing; having to make up a 90-minute block session is like missing two or three sessions under traditional scheduling. Given the mixed findings and limitations with methods used in the studies reviewed, the author called for more research to better assess teacher/student views and to improve understanding of block scheduling effects on student success.

Although block scheduling appears popular among instructors and students, the general education literature provides few insights on the use, and learning effects, of block scheduling for driver education. At least one study suggested block scheduling was more effective on student performance in the third grade of high school when students are generally age 16 and 17, and single scheduling worked better with younger teens in first and second year of high school when their knowledge level was lower. This may have some implications for driver education programs that differ depending on the age at which a student begins the program (e.g., some States offer driver education at age 14.5, others at age 16). Block scheduling may be warranted in those States that start driver education at a later age of 16 whereas single scheduling might work best where driver education can begin at an earlier age. This suggestion, however, is somewhat tenuous because it is based on evidence from a single study. As such, more research is needed to confirm these findings.

The NTDETAS do not deal with the issue of block scheduling directly, but they require courses to consist of classroom/theory instruction with a maximum of 120 minutes per day and BTW instruction with a maximum of 90 minutes per day per student (maybe in addition to classroom instruction provided daily) (p. 20). The ADTSEA Novice Teen Driver Education Curriculum Standards, which forms part of the NTDETAS (Attachment A) calls for sessions of 120-minute training segments (p. 65) (i.e., block scheduling). In practice, however, driver instructors may not teach to the maximum time limits and may have breaks during the day. Since the research evidence is mixed on the efficacy of block scheduling, and considering the findings showing longer sessions may be effective in one educational setting but not in another, there is little or no guidance on the optimal approach that should be adopted for driver education. Whether block or traditional scheduling works best with students in a driver education context is an outstanding issue.

Discussion and Summary

Deliberate practice is defined as purposeful, mindful exercises to improve in a skill/domain with repetition and continuous refinement, in particular activities that are arduous, designed to improve skills progressively (Ericsson et al. 1993). It involves intense effort over a prolonged period for an estimated minimum of 10 years of preparation (Ericsson et al., 1993) to achieve expert performance at the highest level.

It would be unrealistic to expect driver education to require students to devote thousands of hours for at least 10 years of deliberate practice to develop mastery and produce expert drivers like highly skilled athletes or musicians. Rather, the purpose of driver education is to produce competent drivers who, at a minimum, have attained the knowledge and skill level to pass the road test, which is the minimum standard for safe driving. Of course, driver education and the NTDETAS aspire to achieve a much higher standard than just passing the basic road test (i.e., to create safe independent drivers and instill a lifelong process of safe driving).

Research on rapid skill acquisition underscores the importance of deliberate practice but suggests far fewer hours were needed to become competent at a skill rather than the 10,000 hours of deliberate practice to achieve expertise. Rather, 20 hours of deliberate practice is required to sufficiently learn a skill (e.g., Kaufman, 2014). Driver education may have hit its “sweet spot” with 10 hours of BTW driving and instructor-guided activities (homework; feedback to parents on student progress and remedial needs) and driving practice under supervision of a parent/guardian. Under these conditions, driver education may be a potentially effective means of teaching a beginner to become a competent and safe driver. The concept of deliberate practice, however, is only indirectly in the NTDETAS since the standards include BTW with a certified, professional instructor. The critical issue is the extent to which driver education applies deliberate, purposive practice to skill acquisition in driving over the relatively few hours available for instruction and driving practice.

A related and important issue is whether acquiring driving experience truly constitutes deliberate practice given it is not for the explicit purpose of improvement in a set of driving skills. Driver experience is a by-product of the need for mobility and is probabilistic learning in which drivers learn from their experiences as well as by imitation, being influenced by the behaviors of other people (parents, peers, and other drivers) (Boboshi AB, n.d.)**Error! Hyperlink reference not valid.**.

Unlike deliberate practice, the accumulation of driving experience is largely unstructured and develops over time with exposure to diverse driving situations, including risky ones. Drivers in their initial years of driving are not particularly motivated to improve specific aspects of their driving performance. Probabilistic learning and learning by imitation can also have negative consequences, the principal of which are bad habits acquired over time with driving experience. Typically, there is no corrective mechanism to recognize these safe driving errors/mistakes/skill deficiencies and improve them (Ericsson et al., 2007). Further thought and efforts are required to identify effective educational/training or corrective methods that could be applied to deal more effectively with driving deficiencies that develop in experienced drivers.

The NTDETAS also promote the notion of lifelong learning and driver education as an important component in that process but provides no guidance about how to foster and encourage continual deliberate practice. The question is whether fostering lifelong learning, especially outside driver education (e.g., booster sessions), should be the responsibility of driver education and the NTDETAS, alone, or in partnership with the Department of Motor Vehicles (or its equivalent), or some other traffic safety organization or a collaborative effort of like-minded stakeholders concerned about teen driver safety.

Deliberate practice is critical to producing a competent driver and this will rest on the quality of instruction from driver education teachers and the professional development of instructors to ensure they are up-to-date and informed about applying deliberate practice techniques and other educational/training methods to enhance learning (e.g., rapid skill acquisition, spiral learning theories and strategies).

Instructional Hours

The literature suggested traditional driver education (i.e., 30/6/6 model) may fall short of achieving its primary safety objectives because of the short duration of the program, and the challenges of affecting lifestyle and developmental factors (e.g., attitudes, motivations, peer influences) contributing to the elevated crash risk of teen drivers. In recognition that this traditional model may be limited in its ability to effectively teach critical safe driving skills, the NTDETAS, in the first edition of these standards, increased instructional hours from 30 to 45 hours of classroom, BTW from 6 hours to 10 hours, and recommended an additional 10 hours of flexible instruction (e.g., classroom, range, simulation). An increase in the number of instructional hours would be in line with a deliberate practice approach and provides an opportunity for driver education to better address the critical risk factors associated with teen driver crashes. Given the complex nature of these underlying factors (e.g., attitudes, motivation, lifestyle), it may be difficult to modify them but, and importantly, not impossible with the appropriate blend of new content, teaching strategies, and delivery modes, including a better application of deliberate practice. Teacher training/preparation and professional development are a very important part of this solution. This may require breaking down barriers and overcoming teacher/instructor resistance to change.

The challenge is to develop or adopt safety-critical new content and apply more effective delivery modes that can be blended into the core driver education program as substitutes or supplements to subject matter to address key, higher-order, risk factors more effectively. The NTDETAS with the increased instructional hours has the capacity to include potentially effective new content and blended learning activities to address the safety needs of teen drivers more adequately.

Another reason supporting the increased hours for driver education in the NTDETAS is to address emerging issues related, for example, to the rapid growth of in-vehicle safety technologies (advanced driver assisted) and the accelerated move towards automation and electric vehicles over the past few decades (Casner & Hutchins, 2019). Also, smart phone use while driving has become prevalent among teenagers and distracted driving remains a critical risk factor contributing to their crashes (Gershon et al., 2017; Mayhew et el., 2013; Stavrinos et al., 2015). As the vehicle fleet turns over with time and replenishes older vehicles with newer ones that are more automated and technologically advanced, these emerging issues will become increasingly critical to address in driver education now and into the future.

Intensive versus Traditional Delivery of Driver Education

Driver education can be taught over a few days/weeks (so-called crash courses) or spread out over several weeks or months. The limited scientific evidence in the driver education field suggests traditional driver education in which students are taught over a long period of time produces better student outcomes than intensive, short-term, driver training courses. A review of the general education literature on the distribution of learning and the duration of spacing gaps that separate repeated exposure to information supports this conclusion. Research has consistently demonstrated the benefits of spaced or distributed practice over mass or continuous practice (i.e., cramming) (Son & Simon, 2012).

The literature generally suggested longer spacing gaps are better than shorter retention ones, but the benefits of a spacing effect may be eroded if the time interval is too long (Carpenter et al., 2012). The literature, however, failed to identify an optimal spacing gap but underscored there is no 'one-size-fits-all' approach. Establishing spacing gaps depends on when the information is needed and qualified well-trained educators in this approach should be able to identify appropriate spacing gaps that will enhance learning (Hattie, 2003).

The NTDETAS apply a distributed or spaced learning approach requiring "that the acquisition of knowledge and skills is spread over a longer period of days and weeks" (p. 44). The NTDETAS also call for spacing from classroom sessions to sessions outside of the classroom in the form of homework and driving assignments that speaks to the generalization of the subject material and tasks being taught. Having to apply information learned in the classroom to real-world driving practice should derive benefits, in part, from spacing effects. What is not known, however, is whether, in practice, optimal spacing gaps have been established between learning sessions in, and out, of the driver education classroom. The extent to which learners are being re-exposed effectively (for example, by repetition, summary reviews and/or tests; Brenner 1960) to concepts and skills taught in previous lessons is also not known. Consequently, the extent to which driver education can maximize the benefits of distributed/spaced learning is an outstanding issue.

Overlearning and Driver Education

Overlearning relates to the notion of "laboring in vain" and results in diminished or no increases in learning (e.g., practicing a motor learning task over two hours and getting burnt out) (Son & Simon, 2012, p. 384). This finding has relevance for driver education suggesting, for example, that lengthy BTW driving sessions beyond 2 hours may have counterproductive learning effects.

Overlearning is more likely to occur when "cramming" in short, intensive courses and may have only short-term positive effects on retention for both physical and cognitive tasks (e.g., cramming to pass a knowledge or skill test). The NTDETAS do not currently address the issue of overlearning, which might be a useful strategy to assist novices, for example, in passing the DMV knowledge and road tests. They do, however, promote driver education as the foundation for students to continue a lifelong learning process. If the objective of driver education is to produce safer drivers, overlearning may be beneficial in the short-term but may not help novices' longer-term retention of critical safe driving knowledge and skills.

The benefits of overlearning for long-term retention may vary for different types of tasks so the extent to which overlearning is appropriate in some cognitive and motor tasks but not others is an empirical question (Rohrer et al., 2005). Overlearning effects are influenced by not only the kind of task but also the amount of overlearning and the length of the retention period (Driskell et al., 1992). It is not known whether overlearning might have longer-term benefits for specific driving tasks where repetition is applied as a learning method (e.g., braking skills, hazard perception abilities) and as such, the issue of overlearning in relation to driver education remains an outstanding issue.

Block Scheduling and Driver Education

An issue in the general education literature that has relevance for driver education is the practice of block scheduling (e.g., 90-minute class periods) compared to traditional scheduling (e.g., single, 45- or 60-minute class period). The reasoning behind block scheduling was that it resulted in fewer classes, less overwhelming to students, and a more effective use of school time than the traditional single-session approach (Gruber & Onwuegbuzie 2001).

Studies examining the effects of block versus traditional class scheduling have produced mixed results (Gullat, 2006; Gruber & Onwuegbuzie, 2001), including circumstances where this scheduling approach appears to work (e.g., in certain high school grade levels, student ages and knowledge level) (Labak et al., 2020). Some authors recommended mixing block and traditional scheduling to maximize the effects of the two scheduling approaches based on, for example, high school grade and student age (e.g., Labak et al., 2020; Childers & Ireland, 2005). There is at least some evidence that a tri-schedule approach that combines block, traditional and hybrid, was effective in improving most students' satisfaction and grade point average (Gruber & Onwuegbuzie, 2001).

A key factor in the success of block scheduling is instructor preparation and training. Hence, looking forward efforts should focus better on professional development in the adoption of block scheduling. How instructional time is being used and factors that best support the success of block versus traditional, single-session scheduling (i.e., one-size does not fit all) in driver education are not well-understood.

The NTDETAS do not deal with the issue of block scheduling directly, but they require courses to consist of classroom/theory instruction with a maximum of 120 minutes per day and BTW instruction with a maximum of 90 minutes per day per student (maybe in addition to classroom instruction provided daily) (p. 20). In practice, however, driver instructors may not teach to the maximum time limits and may have breaks during the day. Since the research evidence is mixed on the efficacy of block scheduling, and considering the findings showing longer sessions may be effective in one educational setting but not in another, there is little or no guidance on the optimal approach that should be adopted for driver education. Whether block or traditional scheduling works best with students in a driver education context remains an outstanding issue.

Technology-Based Learning and Training as a Supplement to Driver Education

A blended learning approach can involve technology used as a tool in the classroom that may improve learning outcomes. Similarly, in driver education, online, online independent student learning, simulation or virtual/augmented reality training approaches could be beneficial supplements to content and tools employed in driver education. In this regard, the NTDETAS increased instructional hours in the classroom from 30 to 45 hours (e.g., traditional, online, virtual, hybrid), from 6 to 10 hours BTW and further included 10 hours of additional flexible, verifiable instruction. This could include:

- observation,
- BTW,
- range,
- simulation,
- classroom/theory (e.g., traditional, online, virtual, hybrid),
- online independent student learning (e.g., hazard anticipation training); and
- virtual/augmented reality.

Increases in instructional hours enabled driver education to adopt new technological tools and other approaches to more effectively educate and train teen drivers. This section discusses a few of these promising approaches to build on the content and delivery strategies currently employed in driver education and potentially enhance student performance outcomes and safe driving skills.

Driving Simulator Training

Simulation is a technological tool or technique that can be employed for practice and learning/training in relation to many different skill-related activities and domains/fields. It provides a structured, guided learning/training experience and an opportunity for students to practice both simple and complex motor skills, and cognitive abilities in a risk-free environment. As observed by Lateef (2019), it typically seeks to be immersive in nature and attempts to replicate the real world in an interactive, dynamic manner. Simulators provide a means of active learning by letting the student practice specific skills repetitively and by providing immediate feedback on their performance (Thomas et al., 2012).

Simulation is employed as a research and training tool in a variety of diverse fields, including medicine, health care, aviation, rail, and the military. In the field of traffic safety, driving simulators have been used as a research tool "to understand the driver, the vehicle, and the complex driving environment" (Allen et al., 2011). There have been simulator studies examining:

- traffic control devices,
- highway signage,
- vehicle dynamics,

- highway design and driver behavior, including driver texting and cell phone use,
- fatigue,
- inexperience, and
- alcohol and other drug impairing effects (Allen et al., 2011).

According to Ouimet et al. (2011) driving simulation has been used as a research tool to identify factors contributing to the elevated crash risk of young drivers and to evaluate “intervention programs to mitigate risk” (p. 24-2).

Simulators have also been used for training in various fields, especially those in which it is too risky for students to practice in the real-world, and/or those where the expense is too cost-prohibitive to train students to operate a vehicle in a real environment relative to the developmental and operational costs of simulation. In aviation, for example, flight simulators are widely used for training purposes. Studies have shown that simulators reduce the learning period, although Vlakveld (2005) has questioned whether what is learned quickly on a simulator will also be quickly forgotten (i.e., relatively short-retention period).

Flight simulators or other fields of simulator training research (e.g., marine, or military, or medical/healthcare) are perhaps not very relevant to driving simulator training in driver education. This is because of the different motivations of students (e.g., to become a professional pilot and make an income versus to pass a basic road test and drive independently). In the case of students being trained on a flight simulator there is strong motivation to learn because of their employment/career/professional development ambitions, which is not the case for novice teen drivers.

To this end, the flight simulation literature may not be directly relevant because of the potential costs of teaching an inexperienced pilot to fly an aircraft (i.e., potential risk of a critical error precipitating a plane crash), which makes flight simulation training more of a necessity. Human errors while operating an aircraft can have more costly and tragic consequences than driving on-road for training purposes (Saetren et al., 2018). For this reason, and as stated by Vlakveld (2005) “learning to 'maneuver' a plane in a simulator is cost-effective, whereas it is not for learning to maneuver a car” (p. 3).

Simulators are also costly for driver training, but they are not cost-prohibitive, at least for low- to mid-fidelity devices. The use of driving simulation in a driver education setting may also have teaching as well as safety benefits. As observed by Allen et al. (2011), driving simulator scenarios involve the repeated use of cognitive abilities and motor skills in different driving situations, like the real-world driving environment, for the purpose of improving the students’ skills and safety. Simulators have also been shown to be a less stressful learning environment for students and are favored by instructors because they feel safer than being on-road with an inexperienced “neophyte.” This enables instructors to teach higher-order cognitive skills whereas basic skills can be learned/practiced on the simulator (Saetren et al., 2018; Hirsch & Bellavance, 2017).

History and Development of Driving Simulation in Driver Education

According to Wynne et al. (2019), simulators go back to the 1930s (Lauer, 1960) and some type of simulator has been used in driver education courses for decades. In 1951, the Aetna automobile insurance company developed a hands-on driver training tool; a precursor to a driving simulator, called Drivotrainer. As described in Wikipedia, this was:

- "the first combination of automobile simulator and motion pictures designed for behind-the-wheel instruction in drivers' training classrooms. The Drivotrainer classroom has 15 small single seat 'Aetnacars' equipped with controls as similar as possible to those used in actual automobiles. The gas pedal changed the volume of the engine noise, the steering wheel and the clutch and brake pedals provided realistic resistance, even the seat mimicked an actual automobile seat, simulating a realistic on-road driving experience in the safety of the classroom. A motion picture projected on a large screen in front of the room provided the visual stimulus of a drive on streets and highways, while the students 'drove' their simulators. Their responses were collected and recorded on a central unit for the instructor to monitor and correct" (D"Drivotrainer," 2023).

In the early 1970s, Doron Precision Systems took over the Drivotrainer business and has continued to manufacture a wide variety of driver simulator systems since, including ones for driver education. Allstate Insurance was also very active in the development and sales of driving simulators in the 1960s and 1970s (D. Ritzel, personal communication, 2023). Like Drivotrainer, initial systems were fixed-based simulators for group instruction in driver and traffic safety education (NHTSA, 1972). Today, driver simulators are available from many manufacturers of simulation technology.

Several factors promoted the use of driving simulators in driver education. Certainly, simulators are potentially useful tools in driver education because, as Thomas et al. (2012) stated, "it is as close as a person can come to training on real roads with a licensed driving instructor, but without the crash risk" (p. 6). As well, Fox (1960) explained in an early publication on Driver Education and Driving Simulators, the "need to provide driver education to more students has led to the development of driving simulators and this was partly due to the time and costs of dual control vehicle instruction" (p.1) – simulators would reduce per-student costs and the number of teachers needed for one-on-one in-vehicle instruction. This was largely because these early simulators were thought to provide cost-effective "mass training" (p. 50) with students seated in simulated cars watching and responding (steering, braking, accelerating) to a motion picture of driving scenarios projected on a large screen at the front of the room (Fox, 1960). Fox also observed that students learned specific driving skills on a simulator, and in the early years of driving simulators, the author mentioned that this belief resulted in some schools reducing the amount of BTW instruction from 6 to only 3 hours (p. 33).

More recently, Bates, Hawkins, et al. (2019a) suggested driver education could be enhanced by driving simulators because the driver instructor can expose students to a wide and diverse variety of driving scenarios in a short time-period, which would not be feasible for on-road training with an instructor. Driving simulators also have the advantage of ongoing measurement of driving performance (e.g., speed, braking, reaction time) and providing immediate automatic feedback on driving errors (Vlakveld, 2005). In making the case for driving simulator training in Norway, Saetren et al. (2018) described the potential benefits, including:

- "cost-effectiveness,
- environmentally friendly training,
- repeatability,

- accessibility to different scenarios (crash scenarios and dangerous situations, darkness and snow outside of winter, difficult weather conditions and extreme road traffic density),
- the possibility to make errors in a safe environment, and
- interaction with new technology such as advanced driver assistant systems" (p. 2045).

The potential advantages of driving simulator training have become more apparent over the decades due to substantial advances and improvements in driving simulator technology. Indeed, as Allen et al. (2011) described driving simulators have "ranged from a simple set of pedals that a driver reacted with" to the use of "actual car cabs strapped to moving platforms" (Allen et al. 2011, p. 2-1). Driving simulators can be used on a personal computer or in an actual driver's compartment set in an entire multi-million-dollar facility (lab) devoted to the simulator. The software can now replicate almost any type of driving situation (e.g., intersections, rural highways, downtown city streets, high or low traffic volume/patterns, vehicle types/models) and a myriad of environmental conditions (e.g., night or daytime, snow, rain, fog). The simulator environment is truly interactive, and dynamic with single- or several screens displaying 3D scenes and sound effects using central (CPUs) and graphical processing units (GPUs).

Driving simulators today provide a compelling representation of the driving environment and have achieved a high level of face validity (i.e., subjective impression of the realism of the driving situation). In contrast to the early years, however, when driving simulators were viewed as an economical means to test and mass train students in driver education settings, an obstacle to the use of driving simulators in driver education today, especially high-end ones with higher fidelity, is the extreme cost of these devices. Nevertheless, with simulator software and associated hardware (e.g., steering wheel, brake, and accelerator pedals) being available for personal computers, costs have become less of a concern.

Validity, Transfer of Learning, and Safety Effects

There has been a myriad of road safety research using driver simulators. For example, and of special relevance to driver education, simulator research has shown that young inexperienced drivers are less skilled at driving than older experienced drivers in a simulated driving environment (Mayhew et al., under review). Young, inexperienced drivers have been shown with the use of driving simulators, to lack critical cognitive and motor skills that experienced drivers have and are needed to drive safely (Fisher et al., 2017). This research along with crash-based, on-road, naturalistic, and other types of studies has improved understanding of the skill deficiencies of young drivers that need to be addressed. In this regard, there are two critical questions for driver education and the NTDETAS: (1) are driving simulators valid representations of on-road driving? and (2) to what extent does driving simulator training improve the driving skills of teen drivers (i.e., is there a transfer of learning effect from driving simulator training to on-road driving) and ultimately crash reductions?

In relation to the first question, the validity of driving simulators in replicating on-road driving has been questioned and is not well established in the literature. In fact, there have been relatively few validation studies comparing driver performance on a simulator to on-road driving performance (Wynne, 2019). The literature search identified two reviews of driving simulation validation studies. In their review, Mullen et al. (2011) reported that simulators were a valid tool for examining several driving skills, including "speed, lateral position, brake onset, divided attention, and risky traffic behaviors" and "were sensitive to age-related changes in performance and cognition" (p. 13-1). However, there were also measures of driving performance for which driving simulators were not valid, for example, braking force. The authors concluded that driving simulators had relative validity but not absolute validity. Absolute validity occurs when the values measured on the simulator (e.g., mean speed or lateral position) match the values shown on-road, hence simulator driving skills *replicate* those on road. Relative validity refers to when measures on the simulator and on-road demonstrate the same patterns or effects, or simulator driving skills *approximate* on-road driving skills. They also underscored that the validity of a driver simulator should be established for the driver group and its intended purposes; otherwise, the generalizability of the results may be limited and the value of the simulator as a research tool may be compromised. This is especially important because they noted that "a simulator shown to be valid in most settings is not guaranteed to be valid in the next setting" (p.13-16). And driving performance may vary more in simulated than an on-road drive so the authors cautioned that "researchers, driving evaluators, and other simulator users should remain aware that simulators do not always provide an accurate picture of on-road driving behavior" (p.13-14).

In a more recent systematic review of driving simulator validation studies, Wynne et al. (2019; p. 138) examined 44 studies that compared simulated driving to on-road driving using several measures including, mean speed and speed variability, lateral position, overall driving performance, and driving errors. They reported that driving simulators demonstrated absolute or relative validity in about half of the studies, but one-third of the studies reviewed had non-valid results, and the other studies had both valid and invalid results. These mixed results raised questions about the overall validity of driving simulators. They also examined the fidelity of the simulators (low, medium, high), which relates to physical realism (e.g., of the vehicle controls, visual field-of-view [FOV]), to try to understand the mixed results but did not find a clear relationship. For example, low fidelity simulators have the least realism to on-road driving so should be the most likely to produce invalid results, but this was not always the case (e.g., Mayhew et al. 2011).

Importantly, Wynne et al. (2019) argued that given the lack of validity of driving simulators in a sizeable number of these studies that "some of the findings are alarming given that driving simulator studies are widely used to inform road safety policy and practice." They advised authors to "urge caution when interpreting study findings," which often is not done in publications of simulator research, especially if the validity of the simulator is not known (p. 18)**.** Based on their systematic review findings, especially the lack of consistency in validation study methods, Wynne et al. recommended several improvements in the conduct and reporting of simulator studies. These included, for example, better description of the validation results and statistical procedures employed to generate them, and more detail on the simulated driving environment. They also proposed guidelines "for future research to ensure consistency in the conduct, and reporting, of simulator-based research" (p. 138).

Of relevance to the discussion about the importance of establishing the validity of driving simulators, especially in a driver training context, Fox (1960) recognized this several decades ago, when questioning the extent to which the skills learned on a simulator would transfer to real-world driving performance and behavior. As the author pointed out, if there is no transfer of skills from simulator training to driving skills on-road, there is little to be gained from the use of driving simulators. Fox reviewed several small-scale evaluation studies of the Aetna driving simulator and the American Automobile Association's Auto Trainer. According to Fox, this early research showed some transfer of learning effects, but the studies had methodological flaws and results were not generalizable to other driver education situations or settings. According to this author, it was not possible to clearly identify from these studies the type of training effects that were being transferred and the magnitude of the effects.

A recent paper submitted by Hirsch (in press) to ANSTSE in 2021 to update the NTDETAS, referenced the driving simulation training literature to provide a case for increasing driving simulator substitution hours for on-road driving hours in novice driver education. Hirsch contended that driver simulation training research demonstrated transfer of learning (measured by learning time or transfer efficiency) for braking and gear shifting, correct speed adjustment to reduced tire traction, night driving, and backing skills in trucks. A driving simulator training study reviewed also showed students could pass the road test after 9 hours of simulator training and just 30 minutes of on-road practice, and students mastered gear shifting skills on a truck simulator without an instructor better than novice drivers in a real truck with an instructor. Hirsch also pointed out that simulators allowed a greater number of repetitions of training exercises and learning content in fewer hours than on-road training. Based on this review of the driver simulation literature, Hirsch proposed a 50 percent limit for "substituting driving simulator instruction for on-road driver training courses with a minimum of ten hours of on-road hours training.".

Although Hirsch provided a compelling rationale in support of driver simulator training, transfer of learning effects, and increasing the hours to substitute for BTW training, several of these simulation studies relate to truck driver training and were not conducted in a driver education setting. Given the cautionary notes of Mullen et al. (2011) and Wynne et al. (2019) on the absolute and relative validity of driving simulators, albeit as a research tool and not a training platform, it is not clear to what extent transfer of training effects from this research would generalize to teen drivers in driver education. Similar sentiments have been expressed by Bates, Larue, et al. (2019b) in stating "it is not possible to transfer an education program from one platform to another" (p. 36) and that validity and fidelity are "important considerations because research suggests that simulators with different levels of fidelity have different effects on novice driver crash rates" (p. 36).

Research has shown that training on a driving simulator improves simulated driving performance, and to some extent, on-road driving skills. However, these studies typically have small sample sizes that raises concerns about their generalizability. For example, Vlakveld (2005) described an interesting study in the Netherlands in which six novices, with absolutely no driving experience, were trained on a driving simulator for a total of 9 hours with several sequential learning modules and increasing levels of driving complexity. The training lessons covered between vehicle maneuvering skills, the mastery of traffic situations, and calibration (i.e., adapting the driving task to one's skill level knowing one's limitations). Subjects appeared to improve from training module-to-module in almost all skills as measured on the driving simulator. After training completion, the subject's performance was rated on a simulator drive by a professional driving examiner. One subject was rated as ready for the official driving test, four as almost ready and one only about half-way there. The subjects then drove in a vehicle, for the first time, with a driving instructor in the passenger seat. All subjects, however, had difficulty maneuvering the car and Vlakveld noted that "transfer of vehicle handling from a simulator without a moving base to a real vehicle, was quite poor" (p. 2). After a brief in-vehicle training period, focused on braking (about 30 minutes), with an instructor, student performance improved to a point where five of them did a "mock" on-road test with an experienced driving instructor rating their driving performance. The instructor judged that two would have passed the official Dutch drive test, two were just below demonstrating the skills to do so and one was not competent enough. The author suggested this study demonstrated that at least some people can learn to drive and pass the driver license test solely on a driving simulator in a relatively short period of time. Vlakveld cautioned, however, that "this experiment says nothing about the safety performance of these simulator-trained drivers in real traffic" (p. 2).

This appears to be one of the studies Hirsch cited (see above) as providing, presumably, strong, or at least some, rationale for driver simulator training. At best, this Dutch study may provide weak evidence of transfer of training effects on a driving simulator because of the small sample size but, more importantly, because subjects had to take at least a short period of BTW training to maneuver their vehicle adequately, and only two of five subjects (only 40%) were deemed ready to pass the official road test. It is also worth noting that it was a driving instructor not a driver examiner that rated their "mock," on-road, drive test. Also, there was no control group, for example, of teen drivers trained in a traditional driver education program to compare performance on the "mock" drive test. Finally, there did not appear to have been any follow-up of the simulated trained students to determine if any passed the official Dutch road test on their first attempt without further training.

In a more recent systematic review of the literature on the effectiveness of driver simulators for training, Alonso et al. (2023) contended the limited research provided some insights into the value of simulators for improving safe driving performance under risk-free, secure, conditions. However, the authors underscored important study limitations, including small sample sizes, and the lack of follow-up of the training outcomes.

A few studies identified in the literature search examined transfer of learning effects and the safety efficacy of simulated driver training on collision reductions among novice teen drivers. Allen et al. (2007) examined the effects of simulators with three levels of fidelity (low to high fidelity) on crash involvement of simulator-trained teen drivers compared to published data on teen driver crashes in California and Nova Scotia, Canada. The results suggested that all simulators examined reduced crashes, but the higher fidelity simulator with full sized projected displays produced the greatest benefits compared to the crash experience of the control groups. Although an interesting study, results were tenuous, producing very weak evidence because the study design did not use random assignment to intervention and control groups. In other words, many other uncontrolled factors could have accounted for these findings rather than the driving simulator training.

In another crash-based study with a stronger study design, Campbell et al. (2016) randomly assigned 89 high school students to a control group and 126 to driving simulation training. Self-reported information was collected about their crash history and driving infractions, one-year post-intervention. They reported that two-thirds (*n* = 137, 63%) of participants completed the pre-simulator survey, follow-up survey, and obtained a license. Results demonstrated that driving simulation training did not produce a reduction in driving infractions or in motor vehicle collisions. In fact, simulator-trained teen drivers had greater involvement in self-reported crashes than controls (19% versus 12.0%). These results also provide weak evidence regarding the transfer of learning effects of driving simulation for two reasons. First, just over half of these students (64%) completed all 12 modules in the simulation training program. Secondly, the small sample size (*n*=215) was inadequate to detect a significant reduction in crash involvement because as many as 35,000 subjects would be required to reliably detect a 10 percent reduction in crashes (Peck, 2011).

Hirsch and Bellavance (2017) examined transfer of training effects of simulator training on a convenience sample of 1,120 learner drivers in commercial driving schools in Quebec, Canada. Their driving records were compared to young drivers across the province who had completed the mandatory driver education program during the study period. Driving records (i.e., infractions, crashes) were tracked for two years following licensure. The simulator trained group had a lower infraction rate, controlling for vehicle ownership (an indirect measure of greater driving exposure), but their crash rates did not differ significantly. Based on these results, the authors concluded that driving simulator training had "no apparent influence on crashes in the first two years of unsupervised driving after licensing." In a recent systematic review of the driver simulator training literature, Alonso et al. (2023) discussed the Hirsch and Bellavance study and indicated it was discarded from their article search because of biases related to sample selection, and small sample size. Like other evaluations of driving simulator training, the study design of Hirsh and Bellavance provided relatively weak evidence because the study did not randomly assign subjects to intervention and comparison groups and controlled for relatively few factors (e.g., vehicle ownership) so a myriad of other factors associated with teen driver crashes could potentially account for, all or some of, the results.

There has been one recent systematic review of the literature on the safety effects of the use of driver simulators in relation to teen driver behavior and crashes and/or infractions. In their literature search process, Martín-delosReye et al. (2019) identified almost 3,000 references on driver simulator training that speaks to the large volume of research on this issue. However, only five met their rigorous inclusion criteria. The primary reasons for rejecting studies from the review were the lack of a comparison or control group (i.e., non-use of a driving simulator) and the driving simulator was being examined as a research tool and not to assess training effects. According to the authors, the five studies meeting their inclusion criteria were of low quality (small sample size, non-random assignment, not controlling for other factors in the study design/analyses) and results were mixed and inconsistent regarding the outcomes examined. Authors concluded that studies reviewed did not provide consistent evidence to establish that simulated training programs for novice drivers improve their safety performance and called for additional, better, designed studies.

The literature search did not identify further recent literature reviews or evaluation studies of teen driver simulator training employed in a driver education setting. One review study by Bates et al. (2019a), however, has some relevance to this discussion. These authors conducted a scoping review of the literature to examine the use of driving simulators in driver education for two groups of young, disadvantaged people: (a) those with specific impairments or intellectual disabilities and (b) those who have disadvantages associated with their ethnicity (e.g., indigenous youth living in remote areas). The review identified few studies that focused on the efficacy of driver simulators employed in driver education programs, prompting Bates, Hawkins, et al. (2019a) to recommend focusing future attention on the role driving simulators might play with disadvantaged groups in driver education settings.

Implications for Driver Education

The case for driving simulator training in a driver education context is conceptually strong and there are potential advantages of using these devices as a learning tool. However, the research is limited, and although there are some supportive studies, taken together, the evidence is relatively weak. The NTDETAS have driving simulation as one of the delivery modes for the 10 or more additional hours of instruction. Given this approach there is no need for a ratio to substitute driving simulation for any of the 10 hours of BTW training. In this regard, while Hirsch (in press) has argued for a 50 percent substitution ratio, and there is some research evidence to support this, it is mostly tenuous for a variety of reasons. This includes simulation studies with small sample sizes and at best, weak evidence, and studies based on truck driving simulation, which may not be relevant and generalizable to teens in driver education.

The NTDETAS also recommended an increase in classroom instruction from 30 hours to 45 or more hours. It is possible that some of the additional hours could be provided using driving simulation. Ritzel (personal communication, 2023) outlined several potential benefits of this approach:

- Practice difficult maneuvers on fully interactive systems repeatedly until mastered.
- Experience life threatening situations in a completely safe environment.
- Train in adverse weather conditions that is not always possible in real life.
- Train on different terrains like city, hills, highways.
- Train in different real life traffic situations on demand.
- Provide ongoing feedback and "scores" at the end of the drive.

Ritzel suggested using driving simulation as part of the classroom program of driver education would facilitate spending more time teaching young drivers how to be safe and efficient drivers. There is a potential role for driving simulation in driver education, for example, to teach basic vehicle handling skills through repetition of specific motor tasks and procedural maneuvers, and possibly even higher-order perceptual, cognitive skills. This technology may be especially useful for delivering the 10 or more hours of additional instruction to support specific students such as underserved, spectrum, and special needs or accommodations (A. Urie, personal communication, 2023). However, the validity and transfer of learning effects of driving simulation with this high-risk group in a driver education setting needs to be determined.

In this regard, Hirsh provided recommendations to ANSTSE, during the recent update of the NTDETAS, for the minimum standards to be used in a driving simulator. He recommends a 180-degree FOV with rearview mirrors, blind spot displays and accurate representations of the driving environment (e.g., to teach speed control and more complex scenarios such as driving through an intersection). These recommendations should be vetted by subject matter experts in the field of driving simulation, young driver research, and driver education, to reach consensus for the minimum standards for a driving simulator. The outcome could be piloted with novice teens in a driver education setting to determine the simulator's validity with this group of high-risk drivers. If the simulator demonstrates transfer of learning effects and proves to be a valid measure in improving driving performance in the skills taught as demonstrated on a simulated drive-test, and more importantly, on-road, the minimum standards should be adopted in the NTDETAS, and simulator platforms and teaching procedures applied to driver education programs. Further research is also needed with better designed studies to validate simulation training in driver education to determine transfer of learning effects on teen driving performance on road, and in relation to their crash experiences. Some of the elements of well-designed studies have been discussed briefly in this section of the literature review but further efforts should involve the input and consultation of experts in the evaluation of interventions, driving simulation, driver education and traffic safety.

A final note relates to the application of driving simulation to teach higher-order cognitive skills. In this regard, Bates, Hawkins, et al. (2019a), in their review of the driving simulator training literature, observed that in many of the studies the simulator was employed to train vehicle control skills and not higher-order perceptual and cognitive skills. Authors concluded "the studies did not provide any guidance toward which skills should be targeted with simulators, the necessary duration of education in the simulator, whether a simulator could be used as a standalone tool, or otherwise, how to effectively incorporate it within a program" (p. 36).

Regarding using a driving simulator to teach higher-order cognitive skills, Vlakveld (2005) cited Groeger (2000) and Christie and Harrison (2003), who questioned the usefulness of driver simulators for this purpose. This was primarily because higher-order skills require associative learning best acquired over many hours BTW with an experienced driver under diverse driving conditions and road environments, rather than in structured simulator training, which is better suited for teaching basic, procedural driving tasks. Experience appeared to be a more important factor than training here. These thoughts were expressed over 20 years ago, and simulation technology has advanced tremendously since then. As such, the literature on traffic-safety related online and online independent student learning training programs, or what has been termed as simulation techniques (Ouimet et al., 2011), such as hazard perception training is promising and will be discussed in the next section.

Computer-Based and Online Independent Student Learning Approaches to Training

Simulation can be applied on devices ranging from low to high fidelity. Low fidelity devices typically operate on personal computers, or more often today, online and are considered to have lower fidelity because they function without the peripheral apparatus (e.g., pedal, accelerator). In addition, they typically are not as visually representative of real-world driving. Alonso et al. (2023) referred to these types of simulators as "edutainment" because they are intentionally designed to have game-like features and they attempt to combine entertainment and education/training in the learning process. This is like some classroom curriculums, which are also designed with game-like features, so this is not limited to or a unique feature of online independent student learning (B. Van Tassel, personal communication, 2023).

The purpose of this learning approach ("edutainment") is to maintain student attention by using techniques to make the simulated driving experience more fun and not just boring repetition of driving tasks and scenarios. Alonso et al. observed that this technique has been shown to improve short- to long-term memory retention.

Hazard Perception Training

These types of simulation training platforms and techniques have been used to teach higher-order perceptual, cognitive skills, and most often some aspect of hazard perception (e.g., perception, anticipation, awareness, prediction, response, and maintenance). The need for hazard perception training has emerged from decades of research, including on a driver simulator, establishing that young drivers have poor hazard perception skills. These skill deficiencies are a major contributor to teen driver crashes (MacDonald et al., 2015; Fisher et al., 2017). Recognition that poor hazard perception is a serious risk factor for teen and novice drivers has resulted in several jurisdictions outside the United States designing hazard perception tests and using these tests as an integral part of their novice driver testing process to obtain a driver's license (e.g., the United Kingdom and several Australian states; Mayhew et al., 2016). In the United States, Ohio is working on integrating hazard perception into its State driving test (B. Van Tassel, personal communication, 2023).

Mayhew et al. (submitted for publication) recently conducted a comprehensive review of the literature on hazard perception training. The primary focus of this research was to address issues related to teens who are trained and tested in hazard perception abilities using still pictures (photos) of dangerous driving scenes (such as hidden pedestrians or moving vehicles) and video footage of actual driving situations in the Risk Awareness and Perception Training (RAPT+) online student learning program. This hazard perception program has been revised and upgraded several times over the past few decades and it has been evaluated (e.g., Thomas et al., 2016). Authors also identified additional hazard perception training programs that have been developed and evaluated (Mayhew et al., in press):

- **Accelerated Curriculum to Create Effective Learning (ACCEL)** (Fisher et al., 2017) is designed to decrease the time it takes teens to become safer drivers over the first 18 months of independent driving. It focuses on six behaviors: tactical and strategic hazard anticipation, tactical and strategic hazard mitigation, and tactical and strategic attention maintenance.
- **Act and Anticipate Hazard Perception Training** (Meir et al., 2013) is computer-based training to expose young newly licensed drivers to basic handling skills for hazards they may not have encountered, ultimately to enhance their ability to anticipate these types of hazards.
- **Anticipation-Control-Terminate (ACT)** (Muttart et al., 2019) is designed to improve novice drivers' hazard mitigation and speed selection behaviors in left turn across path scenarios. It is a rule-based program consisting of a practice module, a pre-test module, an error-based training and mediation module, and a post-test module. The program includes a video game where drivers must select where to look, where they would steer, and when they would slow when observing the approach to known fatal crash risk scenarios. The program also shows novices how their choices compare to choices made by experienced, crash-free drivers (i.e., drivers 26 through 61 without crashes in the previous 10 years).
- **Automated Online Hazard Perception Training Course for Drivers** (Horswill et al., 2021) is a six-session online hazard perception training course developed in Australia, which incorporates evidence-based learning strategies and footage of over a hundred real crashes. It has five types of exercises: (1) What Happens Next, (2) Commentary Drive, (3) Crash Analysis, (4) Video Review Feedback, and (5) Real World Transfer.
- **DriveFocus** (Alveraz et al., 2019) is an interactive video-based tablet application teaching young drivers how to detect, prioritize and respond to critical roadway items. It

includes six driving scenarios and consists of a general information section, a training section, and a tour section.

- **DriveSmart** (Chapman & Wallace, 2018). includes scenario video-based exercises and attentional control training to develop hazard perception and response skills. Attentional control training is used to improve the ability of novice drivers to allocate attention to the right things at the right time.
- **Engaged Driver Training System** (Krishnan et al., 2015) is a computer tablet-based program to teach novice drivers to anticipate latent hazards and decrease distracting activities in the presence of such hazards. Trainees hold the tablet with their hands and rotate it like a steering wheel to change direction of the vehicle.
- **Game-Based, Multi-user, Online, Simulated Training (GMOST) program** (Arslanyilmaz et al., 2013) is a multiplayer driving simulation game in which all participants may simultaneously drive player vehicles within the same map, and each participant is able to see other player vehicles controlled by other participants in their simulated windscreens and mirrors. GMOST was created to simulate hazard types that were chosen based on the most frequent probable causes of crashes by contributing circumstances.
- **Perceptual and Adaptive Learning Module** (Lerner et al., 2017) for novice drivers is a computer-based adaptive learning program to optimize the efficiency of perceptual learning by using short videos in which the learner must react to scenarios upon detection of a potential hazard. Six categories of hazards are presented, e.g., anticipating another vehicle on the road may move into your path; recognizing where something significant may be obscured from view.
- **SAFE-T** (Yamani et al., 2016) training program integrates RAPT (anticipate latent hazards) with ACT (mitigate hazards) and FOCAL (maintain attention).
- **Situation Awareness Fast Tracking Including Identifying Escape Routes (SAFER)** (Scott-Parker et al., 2018) is a pre-learner intervention for parents to teach their teens situation awareness skills and escape route skills.
- **Secondary Task Regulatory & Anticipatory Program (STRAP)** (Krishnan A. et al., 2019) is designed to improve young drivers' strategic hazard anticipation skills. It trains young drivers to detect clues (e.g., a crosswalk sign) regarding the presence of a potential hazard prior to being able to strategically anticipate the hidden hazard (e.g., a pedestrian at a crosswalk).
- **TeenSmart** (Thomas & Darrah, 2019) is a computer-based driver training program designed to supplement traditional driver education by teaching higher order cognitive skills related to teen driver safety. The program focuses on visual awareness, hazard recognition and risk perception along with several other related crash risk factors: speed and space, gap analysis, critical decision making, lifestyle issues, and distracted driving.
- **Distractology 101** (Zhang et al., 2016) is a training program consisting of two separate training sessions, one on a driving simulator and the other on the internet. The first driving simulator session is 30 minutes showing a different potentially hazardous roadway situation. Each simulator drive is followed by a short instructional video

explaining to drivers why a driver failed to anticipate a hazard or why in-vehicle glances were especially dangerous. The second part of the program consists of 20-minutes of online training reinforcing the skills taught in the first session and the dangers of distracted driving.

As mentioned previously, NHTSA's *Countermeasures That Work* (Kirley et al., 2023) includes a review of hazard perception. It gives the countermeasure a two-star rating. The comprehensive review of evaluation research on hazard perception training by Mayhew et al. (submitted for publication) revealed these programs have generally been shown to improve a variety of aspects of hazard perception, including hazard anticipation, prediction, mitigation, and maintenance skills of young drivers. Such improvements in hazard perception skills from training online or computer-based\online independent student learning have been the case when measured on computer tests, on driving simulators with an eye tracker, and on-road, in real-world driving. Of some importance, the transfer of learning effects of three of these hazard perception training programs (RAPT [Pollatsek et al., 2006; Pradhan et al., 2009], TeenSMART (Thomas & Darrah, 2019) and Distractology 101 (Zhang et al., 2016) were evaluated against crashes and these programs were shown to reduce collision among teen drivers. In the RAPT assessments, safety benefits were demonstrated for male teen drivers and those of lower socio-economic status. The RAPT crash-based study involved random assignment of teens to training and non-training conditions, so it provided strong but inconsistent evidence regarding the safety benefits of hazard perception training (i.e., male teens benefited from the training but not females). In the case of TeenSMART (Thomas & Darrah, 2019) and Distractology 101 (Zhang et al., 2016), although relatively large samples of teen drivers were involved in the studies, there was no random assignment of trained and untrained drivers. Hence, other factors associated with teen driver crashes unaccounted for in the study design/analyses may explain the differences in collisions experienced between the intervention and comparison groups rather than learning on the simulated training interventions (e.g., person-centered characteristics, socioeconomics). Mayhew et al. (submitted for publication) also underscored several other important findings from this review of the hazard perception training literature, including:

- Techniques to measure the various components of hazard perception (e.g., anticipation, maintenance),
- The advantages of shorter, integrated programs, and
- The benefits of brief booster (refresher) training at time intervals after the hazard perception program has been completed (two or three doses, e.g., three and 6 months afterwards) for longer-term retention of knowledge and skills.

Implications for Driver Education

As discussed previously, the NTDETAS includes 10 hours of additional instructional hours with several delivery options and identifies hazard anticipation training as one of these options. The evaluation studies on a variety of hazard perception training programs consistently demonstrated that such training improves the hazard anticipation, prediction, mitigation, and maintenance skills of young drivers as measured on a computer, and on-road driving. There is also some evidence from these studies that hazard perception training may benefit safety outcomes in terms of crash reductions for teen drivers.

Taken together, these results support the use of online independent student learning and/or online hazard perception training as a supplemental delivery option in the classroom or even perhaps as take-home assignments. The challenge is to identify which hazard perception program or programs best fit into the classroom given the different higher-order perceptual, cognitive skills addressed in the training. As well, an important consideration would be to identify the programs that best serve as "edutainment," a combination of entertainment and education/training. These types of programs capture student attention to ensure program completion and better memory and skill retention in the short and longer term. Ideally, and if feasible, the design/development of a contemporary hazard perception program that incorporates the best features of those programs proven effective in improving teen driver hazard perception skills and driving performance would advance the field of simulator training and potentially improve teen driver safety. It may also be possible to adopt hazard perception and other computer-based/online programs that are already available. The validity, fidelity, and transfer of learning effects of this newly designed hazard perception and/or other higher-order skills training programs will need to be determined.

Virtual Reality and Driver Education

Virtual reality (VR) is a technology that dates back to the mid-1800s and the concept of stereopsis, meaning related to depth perception and binocular vision. Another major milestone occurred in the mid-1950s when a cinematographer created Sensorama, the first 3-D VR machine housed in a booth (patented in 1962; Barnard, 2023). Like simulation, VR is an immersive, interactive experience that attempts to emulate the real-world environment by engaging the visual, auditory, and tactile senses (Xie et al., 2021). It involves a head-mounted device or helmet with displays to create a realistic 3-D world. VR hardware may also include controllers, tracking systems, headphones, wearable haptic VR clothing, and the VR device may also let the user walk around freely (Xie et al., 2021). At the higher level of total immersion, the VR user perceives a physical presence in the non-physical world (Drożdż, 2021). In this regard, VR mimics and influences the key human senses; visual, auditory, haptic, kinesthetic, and olfactory.

VR devices produce a 3-D environment with higher resolution graphical quality, better visual flow, and a higher sense of realism than can be achieved on driving simulators. They are also more flexible and portable devices, especially in comparison to high-fidelity, motion-based, fixed-driving simulators (DeLuca et al., 2023; Marks et al., 2014; Mangalore et al., 2019). According to Xie et al. (2021), VR technology is more available now at relatively low cost because of "the recent growth of consumer-grade VR devices" (p. 1).

VR as a Learning/Training Tool

VR is becoming popular as a learning/training tool in education, health, aviation, military, and workplace settings, for example, in hazardous occupations such as with first responders, to train students/employees in the performance of real-world tasks and procedures (Xie et al., 2021; Stefan et al. 2023). This is because VR training applications are highly interactive or as described by Jakab (2018), in a review of the VR literature, this technological tool applies a "learning-by-doing methodology" (p. 5). Such an approach contributes to improved retention of information and skill development in a risk-free environment. The advantages of VR training also include an increased level of engagement, which is achieved by providing individual training outcomes and learning from other VR users. In addition, VR enables personalized learning (i.e., in the comfort of their office at work, including at home) by setting the pace of learning to the person and VR training to be used anytime, anywhere, on several devices (Xie et al., 2021; Drożdż, 2021). VR training is also viewed as an effective learning approach that potentially can reduce training costs (Xie et al., 2021). According to Xie et al. (2021, p. 2), VR training addresses several of the key limitations of real-world training, which include:

- time-consuming because of the effort and time required to both maintain the training facility and travel to the facility;
- expensive because of the cost of real-world training material and hiring instructors/coaches;
- unappealing and difficult to learn because of the lack of visual images and cues to illustrate skills and methods; and
- difficult or impractical to teach some skills in the real world because of the inherent risks of bodily harm, such as responding to emergencies and natural disasters, that can only be safely trained in a simulated environment.

An important limitation of VR, however, is that some people are susceptible to cybersickness, which is like simulator sickness and relates to visual stimulation; it can be mitigated by closing one's eyes (Jakab, 2018). According to several studies, age affects cybersickness with older people being less susceptible. This suggests younger people in the age range of students in driver education may be more prone to suffer from this side-effect (Jakab, 2018; Dilanchian et al., 2021; Garrido et al., 2022).

Validation, Transfer of Learning, and Safety Effects

The literature on VR includes validation and transfer of learning studies suggesting that VR approaches provide a valid measure of skill performance and VR training improves knowledge and skills at least as measured on VR devices, driving simulators or self-report (Mangalore et al., 2019; Strojny & Dużmańska-Misiarczyk, 2023). Regarding validation, the literature search identified one study related to the use of VR technology to measure driving skills. Mangalore et al. (2019a; 2019b), in a master's thesis and published article, examined the validity of a VR headset-based driving simulator for measuring hazard anticipation skills. In the study, 48 young (18- to 21-year-old) and older (30- to 55-year-old) subjects were randomly assigned to a driving simulator or a head-based VR simulator. Results showed experienced drivers anticipated more latent hazards (i.e., not visible but are likely to emerge) than young drivers on both the VR and driving simulator tests. Older subjects also glanced longer at latent hazards than younger ones on both devices as measured by total glance duration but not by the average glance duration. The author also noted the severity of simulator sickness did not differ significantly for the VR head-set approach and the driving simulation. Mangalore et al. (2019b; also reported by Fitzpatrick et al., 2019) concluded that these findings provide some support for the use of VR headsets as a research tool to better understand hazard anticipation skills as well as other skills and behaviors of drivers. These authors further suggested their findings along with other hazard perception research could be used to better design a risk awareness training program.

There have been a several systematic reviews and/or meta-analyses of VR training effects, overall, (Strojny & Dużmańska-Misiarczyk, 2023) and in a diversity of fields, including education (Yu & Xu 2022; Kim & Im, 2022), health profession education (Kyaw et al., 2019), nursing (Woon et al., 2021), and vocational work (Radhakrishnan et al., 2021)**.** All these systematic reviews and meta-analyses have identified studies demonstrating benefits of VR training in positively influencing learning outcomes in terms of knowledge gains, skill improvements, and shorter learning periods in mastering skills relative to traditional and other training methods. For example, in their recent review of VR effect studies, Strojny and Dużmańska-Misiarczyk reported that most studies had positive results with a significant gain in learning outcomes, and VR training outperformed traditional methods, and non-training. In a few studies, VR training was as effective as traditional learning and only a smaller number of studies found VR not effective (i.e., no differences between methods) or had a lower effect than traditional training methods. In terms of student reactions or attitudes towards VR training, almost all studies indicated positive subjective assessments.

Of some interest, authors cited a study by Jong (2015) that showed VR training effects were associated with pre-learning achievement in that VR training, compared to traditional methods. The VR training was less effective with high-achieving students, equally effective with moderately achieving students, and more effective for low-achieving students. These results suggest VR training effects vary with the pre-learning achievement level of students and underscores the importance of pre-testing students to determine which would benefit most from a VR training tool versus traditional learning or other delivery methods. However, since this observation was based on a single study, the relationship between a student's pre-learning achievement and VR training relative to other training approaches remains an outstanding issue.

A key question regarding studies of VR training effects, however, is the strength or veracity of these findings that depends on the method and measures applied to investigate the effectiveness of the VR training technology (e.g., sample size, the use of an experimental pre-post training design with controls/comparison groups, performance improvements as measured on a VR test, driving simulator or under real-world conditions). In this regard, in a recent study, Stefan et al. (2023) conducted a systematic review of 136 studies examining the effectiveness of VR training in safety-related fields, including 5 studies on VR training in transportation/road safety. Authors focused on how studies evaluated the effectiveness of VR safety-relevant training and not on the findings or quality of these validation studies. Although this systematic review does not provide information on the benefits of VR training it does provide insights into the methods and outcome measures typically applied to evaluate VR training that speaks to the strength of the evidence. Authors reported that most evaluation studies on health-related VR training focused on learning outcomes (knowledge and skills acquired) and student/trainee reaction or attitudes toward the training. They did not find any study examining changes in students' behavior after training and only a few focused on the primary training objectives, such as a reduced number of safety incidents and/or crashes. Learning outcomes were most often measured on VR performance tests and knowledge tests with relatively few studies measuring transfer of learning effects (only 26 of 136 studies reviewed).

Similar observations on the methodological limitations of VR training studies were expressed in a recent review of the literature by Strojny and Dużmańska-Misiarczyk (2023). Of the over 4,500 records initially identified in the literature search, authors reviewed 330 studies on the effectiveness of VR training that met their inclusion criteria; VR training studies on medical procedures were excluded because the authors judged there were already too many systematic reviews on this specific topic. They determined VR training studies focused primarily on student reactions/attitudes towards VR technology and learning outcomes, not behaviors or impacts on real-world events (e.g., loss work time, crashes, injuries). Other limitations of VR training studies noted by these authors, included:

- the skill or knowledge test is, typically, conducted immediately after training so knowledge gain and/or skill retention is not known days, weeks or even months after completing the VR training;
- sample sizes that are not adequate to perform statistical analyses, and produce results that are generalizable to a broader group of people or situations;
- missing information on the number and duration of VR training sessions;
- no control or comparison groups;
- simple and informal assessment and comparison methods without statistical tests to determine if differences are significant and to estimate effect size;
- publication bias in that there is no information on how many studies produced non-significant or negative results of VR training because such studies are seldom or never published.

Authors concluded there was a lack of systematic and methodologically sound evaluation of VR training and findings from existing studies showing the benefits of VR training should be treated with caution. They also observed that their findings underscored the need for further research on the effects of VR training. In this regard, Woon et al. 2021, in their systematic review of the literature on VR training, called for larger, well-designed random control trials to strengthen the evidence about the effectiveness of VR training.

Taken together, however, the results that emerged from the VR training studies are promising and provide at least some support for the use of virtual reality training in driver education/training to teach novices knowledge and skills related to driving safely. This is especially the case because the few studies evaluating VR training to improve driving skills have shown enhanced driving performance and potential safety benefits. Xie et al. (2021), for example, cites a study by Lang et al. (2018) to design a personalized VR training system to correct driving errors. An eye tracking VR headset was initially used to identify driving errors and poor driving habits such as not checking blind spots or not signaling before turning or not paying attention to pedestrians. Eye movement data were used to design a personalized training route letting students encounter scenarios and practice skills to correct their driving errors. In this regard, the VR training system operates like a driving coach or instructor (i.e., identifies problems and allows practice, and repetition, to correct mistakes).

Lang et al. (2018) validated their VR training approach with a user study that compared their VR system with other training methods (e.g., books, videos). The study comprised a sample of 50 subjects with one to 20 years of driving experience randomly assigned to five groups: personalized VR training, traditional VR training, safety training video, driving handbook manual, and no-training. Pre-evaluation scores and response times (as a measure of sensitivity to emergencies) on a VR test drive were compared to post-training VR tests immediately after training and one week later. The driving skill level of the five groups of subjects were comparable on the VR assessment before training. After training, driving test scores of the personalized VR trained group were significantly higher than the comparison groups, suggesting to the authors that this personalized VR approach was “more effective than the other approaches in terms of improving driving skills” (p. 302). This was also the case when subjects were re-assessed one week after training as those completing personalized VR training had similar driving test scores as they had post-training and those in the other groups generally declined over this one-week follow-up period. Training effects were also observed for response time with the personalized VR group having significantly greater improvement in response time post-training compared to the other training methods and for those not receiving training. One week after training, the personalized VR group had almost the same response times as post-evaluation and the response times of the other trained groups worsened to almost the level of those untrained. Authors concluded that personalized VR training produced a “more persistent training effect” (p. 303).

As acknowledged by Lang et al. (2018), the primary limitation of this study was that transfer of learning effects was not assessed in relation to real-world driving. The results, however, provide some evidence that a personalized VR training approach improves problematic driving habits and mistakes and improves driving performance relative to other training methods, at least as measured on a VR drive test. Authors also stated that this approach could complement traditional driver training but not substitute for it as instructors or coaches were still needed for students to learn “all the basic driving skills” necessary for driving safely on road in real traffic.

The literature search identified another study on VR effectiveness that is especially relevant to driver education because subjects were novice drivers. Jakab (2018) examined the effectiveness of VR training on the driving performance of a small sample of 11 inexperienced drivers. The author found that driver performance improved significantly over five brief VR driving sessions as measured on VR tests. Statistically significant findings, however, were only found between the first and last VR training sessions, suggesting that training effects were incremental and difficult to detect from one session to the next. Based on these findings and recognizing further studies of VR training were needed, the author recommended that VR training could potentially be applied to supplement BTW training, especially when training skills in risky situations, which would not be feasible in on-road training.

Like driving simulators, VR systems have also been used to train aspects of hazard perception skills. Agrawal et al. (2018), for example, evaluated a VR headset-based latent hazard anticipation and mitigation training program (V-RAPT). Subjects comprised 36 young drivers who were randomly assigned to V-RAPT or two other conditions – risk awareness and perception training (RAPT, a PC-based, driver simulation technique) and no training (a PC-based placebo training program with no feedback on driving performance and no instructions on latent hazards but rather information on how to gauge tire pressure). The hazard anticipation and mitigation skills of subjects were measured by eye movement (head mounted, eye tracker) and vehicle data on a driving simulator. Agrawal et al. reported that V-RAPT drivers, compared to RAPT drivers and the placebo trained group, anticipated more latent hazards and were better at mitigating potential hazards. Regarding hazard anticipation, better performance for VR-trained drivers was the case for both near-transfer driving scenarios (i.e., like the training scenarios) and far-transfer scenarios (i.e., not closely related to the training scenarios). They concluded that VR training had the potential to improve skills related to anticipation and mitigation of hazards; critical factors that contribute to young driver crashes.

Although the above studies about the benefits of VR training in improving driving-related skills (e.g., driving errors/mistakes; hazard anticipation and mitigation skills) are promising, all of them suffer from some of the same methodological limitations discussed previously about the effectiveness of VR training in other fields/domains. Principal of these issues are:

- small sample sizes so results may not generalize to other teen drivers or settings;
- subjects older than teen drivers aged 15-17, the age range typically in driver education;
- studies using subjects with some driving experience, which means that results may not reflect the effect of VR training on this younger inexperienced group of learner drivers, typically in driver education programs; and
- the use of VR or driving simulator test measures, and not on-road driving performance or crash reductions or near-misses as a basis to assess the positive effects of VR training on skill improvement/development.

The VR training technology appears promising but, as several authors concluded, more research is needed.

Implications for Driver Education

In the NTDETAS, provisions are made for VR as an optional delivery tool in the minimum 10 additional instruction hours. VR training would likely be less expensive than driver simulator training and potentially let multiple users interact together in VR learning sessions. Under these circumstances, VR training could be used in the laboratory phase of the driver education classroom and/or as a learning tool to move from the traditional 30 hours of classroom instruction to the recommended 45 hours in the NTDETAS. Since VR headsets/googles are portable, it might also be possible to assign VR training homework so students could practice driving skills, initially introduced in the classroom or BTW, remotely from the classroom and driving instructor, in a risk-free environment.

Of importance to this discussion, in the NTDETAS, virtual reality is defined along with augmented reality (AR) as one term or concept as "the computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors. Can be used for drivers to safely practice traffic rules, hazard awareness, and general driving behavior" (p. 52). Although this definition captures the meaning of VR/AR technology in a broad or general sense, technically, VR differs from AR in important ways. VR is completely virtual, replacing the user's vision and perceptions of the real-world, whereas AR users can observe their real surroundings with an AR device, adding to it by overlaying the physical world with a virtual scenario. In this regard, users can still control their presence in the real world and augmented reality is the real world enhanced by virtual objects/images. An example of AR is the heads-up display on the windshield of a vehicle or observing a virtual vehicle racing down the street in front of the user. AR can even operate on a smartphone (e.g., used in games such as Pokémon GO) or smart glasses (e.g., Google Glass or Microsoft HoloLens).

There is a burgeoning body of research on AR as a tool to measure and train skilled performance. Like VR research, AR studies have demonstrated that this technology has user satisfaction and instructor acceptance, is a valid research tool in measuring a user's/student's skills, has improved knowledge and skills, and has transfer of learning effects (Ritter et al., 2007; Kucuk et al., 2014; Barsom et al., 2016; Fida et al., 2018; Chen et al., 2019; Ibili et al., 2019; Mustami et al., 2019;

Sahin & Yilmax, 2019 ; Buchner et al., 2021; Huda et al., 2021; Chiang et al., 2022; Suresh et al., 2022). AR research, however, has the same methodological limitations as VR and driving simulator research, such as, typically, small sample sizes, measures related to skill improvements only on AR tests and/or driving simulators, self-reported information. Driver education may be an optimal setting to further establish the efficacy of such technological learning tools and recommend new and novel approaches to enhance the learning environment in the future.

Virtual reality training to teach driving skills is relatively straightforward in that the application can replicate or reproduce aspects of driving and the focus can be on basic and/or higher order driving skills. The application of AR to driver training is perhaps less apparent/obvious because images/visuals are overlaid on the real-world experience. AR training may be the optimal learning tool to supplement lessons guided by an instructor, for example, in the classroom or on a range, to simultaneously combine theoretical concepts and information being taught by an instructor and overlay/superimpose, on a headset or AR glasses, real-time visual practical applications. As such, AR may facilitate and enhance the instructor's lesson by interweaving theory (ideas and concepts) and practice (the application of knowledge or skills). The extent to which AR becomes a distraction and may be counterproductive to the learning experience, however, would need to be determined.

Discussion and Summary

Technology-based learning, including online, online independent student learning simulation or virtual/augmented reality training, could be beneficial supplements to content and tools employed in driver education. The NTDETAS increased instructional hours and enhanced the capacity of driver education to adopt new technological tools and other approaches to more effectively educate and train teen drivers.

Simulation Training

Simulation is a technological tool or technique that can be employed for practice and learning/ training in relation to many different skill-related activities and domains/fields. In the field of traffic safety, driving simulators have been used as a research tool "to understand the driver, the vehicle, and the complex driving environment" (Allen et al., 2011), to identify factors contributing to the elevated crash risk of young drivers, to evaluate "intervention programs to mitigate risk" (Ouimet et al., 2011, p. 24-2), and to train novices in how to operate a motor vehicle safely.

Simulators may have teaching as well as safety benefits because driving simulator scenarios involve the repeated use of cognitive abilities and motor skills in different driving situations, like the real-world driving environment, for the purpose of improving the students' skills and safety. The instructor can expose students to a wide and diverse variety of driving scenarios, repeatedly, in a short time and risk-free environment that would not be feasible for on-road training with an instructor. Driving simulators also have the advantage of ongoing measurement of driving performance (e.g., speed, braking, reaction time) and providing immediate, automatic feedback on driving errors (Vlakveld, 2005). The potential advantages of driving simulator training have become more apparent over the decades as there have been dramatic advances and improvements in driving simulator technology.

The validity of driving simulators in replicating on-road driving has been questioned and is not well established in the literature. Research on transfer of learning effects has shown that training on a driving simulator improves simulated driving performance, and to some extent, on-road driving skills. However, these studies typically have small sample sizes that raises concerns about their generalizability.

A few studies identified in the literature search examined transfer of learning effects and the safety efficacy of simulated driver training on collision reductions among novice teen drivers. The research is limited, however, and although there are some supportive studies, taken together, the evidence is relatively weak because of methodological issues with these studies (e.g., small sample sizes, lack of random assignment). Nonetheless, the case for driving simulator training in a driver education context is conceptually strong and there are potential advantages of using a driver simulator as a learning tool.

The NTDETAS have simulation as one of the delivery modes for the 10 or more additional hours of instruction. The NTDETAS also recommended an increase in classroom instruction from 30 hours to 45 or more hours and some of these increased hours could be with simulation to facilitate teaching young drivers how to be safe and efficient drivers. There is a potential role for simulation in driver education, for example, to teach basic vehicle handling skills through repetition of specific motor tasks and procedural maneuvers, and possibly even higher-order perceptual, cognitive skills. This technology may be especially useful for delivering instruction to support specific students such as underserved, spectrum, and special needs or accommodations (A. Urie, personal communication, 2023). The validity and transfer of learning effects of simulation with this high-risk group in a driver education setting.

The use of simulation in driver education should be vetted by subject matter experts in the field of simulation, young driver research, and driver education. The goal would be to reach consensus about the minimum standards for driving simulators that could then be piloted with novice teens in driver education settings to determine the simulators validity. If the simulator demonstrates transfer of learning effects and proves a valid measure in improving driving performance in the skills taught as demonstrated on a simulated drive-test, and more importantly, on-road, the minimum standards could be adopted in the NTDETAS, and simulator platforms and teaching procedures applied to driver education programs.

Computer-based and Online Independent Student Learning Approaches to Training

Driving simulation can be applied on devices that range from low to high fidelity. Low fidelity devices typically operate on personal computers, or more often today, with software online and are considered to have lower fidelity because they function without the peripheral apparatus (e.g., pedal, accelerator) and are, typically, not as visually representative of real-world driving. These types of simulation training platforms and techniques have been used to teach higher-order perceptual, cognitive skills, most often some aspect of hazard perception like perception, anticipation, awareness, prediction, response, and maintenance.

Mayhew et al. (in press) recently conducted a comprehensive review of the literature on hazard perception training. This review revealed that hazard perception training programs have generally been shown to improve a variety of aspects of hazard perception, including hazard anticipation, prediction, mitigation, and maintenance skills of young drivers. Such improvements have been the case when measured on computer tests, on driving simulators with an eye tracker, and on-road, in real-world driving. Of some importance, the transfer of learning effects of several hazard perception training programs were evaluated against crashes and these programs were shown to reduce collisions among teen drivers, although in one study findings were mixed (e.g., crash reductions for male but not for female teen drivers), and other studies had methodological limitations, principal of which was no random assignment of trained and untrained drivers, so other factors, and not training, might explain the crash reductions.

The NTDETAS include 10 hours of additional instructional hours with several delivery options, and, in fact, identifies as an example hazard anticipation training as one of these options. Taken together, research on hazard perception training supports the use of online independent student learning and/or online hazard perception training as a supplemental delivery option in the classroom or even perhaps as take-home assignments. The challenge is to identify which hazard perception program or programs best fit into the classroom and driver education program given the different higher-order perceptual, cognitive skills being addressed in the training. Ideally, and if feasible, the design/development of a contemporary hazard perception program that incorporates the best features of those programs proven effective in improving teen driver hazard perception skills and driving performance would advance the field of simulator training and potentially improve teen driver safety. The validity, fidelity, and transfer of learning effects of this newly designed hazard perception and/or other higher-order skill training programs (e.g., distracted driving).

Virtual Reality and Driver Education

Like simulation, VR is an immersive, interactive experience that attempts to emulate the real-world environment by engaging the visual, auditory, and tactile senses (Xie et al., 2021). At the higher level of total immersion, the VR user perceives a physical presence in the non-physical world (Drożdż, 2021). These devices are more flexible and portable (i.e., head mounted device or helmet), especially in comparison to high-fidelity, motion-based, fixed-driving simulators (DeLuca et al., 2023; Marks et al., 2014; Mangalore et al., 2019).

VR is becoming popular as a learning/training tool in education, health, aviation, military, and workplace settings, for example, in hazardous occupations such as with first responders, to train students/employees in the performance of real-world tasks and procedures (Xie et al., 2021; Stefan et al. 2023). This is because VR training applications are highly interactive and apply a "learning-by-doing methodology" (Jakab, 2018; p. 5) that contributes to improved retention of information and skill development in a risk-free environment.

The literature on VR includes validation and transfer of learning studies suggesting that VR approaches provide a valid measure of skill performance and VR training improves knowledge and skills at least as measured on VR devices, driving simulators and/or self-report (Mangalore et al., 2019; Strojny & Dużmańska-Misiarczyk, 2023). There have been several systematic reviews and/or meta-analysis of VR training effects, overall, that have identified studies demonstrating benefits of VR training in positively influencing learning outcomes in terms of knowledge gains, skill improvements, and shorter learning periods in mastering skills relative to traditional and other training methods.

Systematic reviews on the validity of VR training studies, however, underscored a lack of methodologically sound evaluations and suggested that findings from existing studies showing the benefits of VR training should be treated with caution. According to these critical reviews, there is a need for further research on the effects of VR training (i.e., larger, well-designed random control trials to strengthen the evidence about the effectiveness of VR training) (Woon et al., 2021).

Taken together, however, the results that emerged from the VR training studies are promising and provide at least some support for the use of virtual reality training in driver education/training to teach novices knowledge and skills related to driving safely. This is especially the case because the few studies evaluating VR training to improve driving skills (e.g., driving errors/mistakes; hazard anticipation and mitigation skills) have shown enhanced driving performance and potential safety benefits. Although the results from these studies are promising, all of them suffer from some of the same methodological limitations discussed previously about the effectiveness of VR training in other fields/domains (e.g., small sample size, the use of VR or driving simulator test measures, and not on-road driving performance).

In the standards, provisions are made for VR as an optional delivery tool in the minimum 10 additional instruction hours. VR training would likely be less expensive than driver simulator training and potentially let users interact together in VR learning sessions. Under these circumstances, VR training could be used in the laboratory phase of the driver education classroom and/or as a learning tool to move from the traditional 30 hours of classroom instruction to the recommended 45 hours in the NTDETAS. Since VR headsets/googles are portable it might also be possible to assign VR training homework so students could practice driving skills, initially introduced in the classroom or BTW, remotely from the classroom and instructor, in a risk-free environment.

In the NTDETAS, virtual reality is defined along with augmented reality (AR) as one term or concept. Although the definition captures the meaning of VR/AR technology in a broad or general sense, technically, VR differs from AR in important ways. VR is completely virtual, replacing the user's vision and perceptions of the real-world, whereas AR users can observe their real surroundings with an AR device, adding to it by overlaying the physical world with a virtual scenario. Users can still control their presence in the real world and augmented reality is the real world enhanced by virtual objects/images.

Like VR research, AR studies have demonstrated that this technology has user satisfaction and instructor acceptance, is a valid research tool in measuring a user's/student's skills, has improved knowledge and skills, and has transfer of learning effects. AR research, however, has the same methodological limitations as VR and driving simulator research (e.g., typically, small sample sizes, measures related to skill improvements only on AR tests and/or driving simulators, self-reported information). Future consideration should focus on the extent to which driver education may be an optimal setting for such technological learning tools. It is possible the NTDETAS should be expanded to include new and novel technological approaches to enhance the learning environment in driver education settings in the future.

Virtual reality training to teach driving skills is relatively straightforward in that the application can replicate or reproduce aspects of driving, and the focus can be on basic and/or higher order driving skills. The application of AR to driver training is perhaps less apparent/obvious because images/visuals are overlaid on the real-world experience. AR training may be the optimal learning tool to supplement lessons guided by an instructor, for example, in the classroom or on a range, to simultaneously combine theoretical concepts and information being taught by an instructor and overlay/superimpose, on a headset or AR glasses, real-time visual practical applications. As such, AR may facilitate and enhance the instructor's lesson by interweaving theory (ideas and concepts) and practice (the application of knowledge or skills).

Final Thought

The decision of using driving simulators versus simulation techniques versus VR versus AR in driver education may not be to select one delivery tool over the others. It is possible that all or a few of these technological approaches to training could be applied in driver education but for different learning purposes (e.g., driver simulator to teach intersection, higher-speed freeway, and nighttime driving, simulation techniques to address hazard perception and other higher-order cognitive skills, VR to cover distracted driving and alcohol/drug impaired driving effects, and AR to teach basic vehicle control skills, vehicle maintenance and rules of the road). Further consideration, for example, through subject matter expert consultations, is needed to identify the optimal applications of these technological learning approaches in a driver education context.

Conclusions

The most recent NTDETAS were released in May 2023. The NTDETAS are based on expert opinions from subject matter experts in the field of driver education and traffic safety, and scientific evidence from the literature. However, there are research questions that must be answered to fill information gaps, to help define what works and what might not in the field of driver education and training. This review of the driver education and general education literature identified studies in relation to three primary issues to determine if there is evidence to support their use: the value of blended learning, the use of deliberate practice, and the application of technology-based approaches.

Blended learning refers to a learning approach involving face-to-face and online activities that supplement and/or substitute for what is taught face-to-face in the classroom. The NTDETAS incorporate a blended learning approach in several ways. First, the NTDETAS call for several delivery methods with minimum instructional hours, including classroom (45 hours), and BTW training (10 hours), as well as 10 additional hours using a variety of delivery modes, such as observation, behind-the-wheel, range, simulation, classroom/theory (e.g., traditional, online, virtual, online independent student learning [e.g., hazard anticipation training]); and virtual/augmented reality. The NTDETAS also accommodates a form of blended learning that explicitly provides standards for learning to be delivered by some combination of face-to-face, virtual, and online activities. In the 2023 NTDETAS, online education has become integral to the delivery of driver education, as a supplement to face-to-face classroom activities. These updates demonstrate that the NTDETAS have adopted a blended learning approach for driver education. Based on the findings from this literature review, the NTDETAS and the subject matter experts that developed and updated it, are on solid footing in adopting a blended learning approach and ensuring there is flexibility in the design of the blend. This flexibility in design lets State driver education administrators tailor their programs to address the needs of students in their State and adopt and blend the teaching tools best suited to augment and build upon the abilities and experiences of their driving instructors to facilitate achieving course objectives.

Deliberate practice is defined as purposeful, mindful exercises to improve in a skill/domain with repetition and continuous refinement, in particular activities that are arduous, designed to improve skills progressively over a long time (10 or more years; Ericsson et al., 1993). Deliberate practice was initially studied as a method to achieve expertise in motor skills (e.g., sports, music). It would be unrealistic, however, to adopt this deliberate practice concept in a driver education context to develop mastery and produce expert drivers like athletes or musicians. Rather, the purpose of driver education is to produce competent drivers who have attained the knowledge and skill level to pass the road test, which is the minimum standard for safe driving and provides a means to determine if a learner driver has achieved that standard (Mayhew et al., 2016). Of course, driver education and the NTDETAS aspire to achieve a much higher standard than just passing the basic road test (i.e., to create safe independent drivers). The critical question is whether 10 hours BTW driving with a qualified instructor and additional related hours of on-road practice under supervision is sufficient time to become a competent and presumably safe driver upon completion of driver education.

However, the empirical question remains: Can deliberate, or even simple, practice improve the level of skills in a relatively short learning/training period to achieve competency in a field or domain? The literature on rapid skill acquisition suggested that 20 hours or more of deliberate practice may be adequate to produce competency in a skill or activity. In this regard driver education may have hit its "sweet spot" with 10 hours of BTW driving and instructor guided activities (homework, feedback to parents on student progress, and remedial needs) and driving practice under supervision of a parent/guardian. The critical issue is the extent to which driver education applies deliberate, purposive practice to skill acquisition in driving over the relatively few hours available for instruction and driving practice. This may be particularly problematic because teachers and instructors in driver education are typically focusing on an hourly standard rather than purposive practice during lessons (R. Hanson, personal communication, 2023).

The literature on technology-based approaches suffers methodological weaknesses but studies consistently reported improved skill performance and, therefore, are promising for driver education. Such approaches can be added as a tool to a blended classroom, which may improve learning outcomes. Online, virtual, online independent student learning, simulation or virtual/augmented reality training could be beneficial supplements to, content and tools employed in driver education. In this regard the NTDETAS recommends increases in instructional hours from 30 to 45 or more hours in classroom (e.g., traditional, online, virtual, hybrid), from 6 to 10 hours or more BTW and added 10 hours of additional flexible, verifiable instruction, such as observation, behind-the-wheel, range, simulation, classroom/theory (e.g., traditional, online, virtual, hybrid), online independent student learning (e.g., hazard anticipation training); and virtual/augmented reality. The NTDETAS increases in instructional hours enhance the capacity to adopt new content delivery strategies, technological tools, and other approaches to more effectively educate and train teen drivers. When making the decision of which delivery tools to use in driver education (e.g., driving simulators, simulation techniques, VR, or AR) it may not be to select one delivery tool over another. It is possible that all or a few of these technological approaches could be applied but for different learning purposes (e.g., driver simulator to teach intersection, higher-speed freeway, and nighttime driving; simulation techniques to address hazard perception and other higher-order cognitive skills; VR to cover distracted driving and alcohol/drug impaired driving effects; and, AR to teach basic vehicle control skills, vehicle maintenance and rules of the road).

The application of technological approaches, however, should be approached cautiously. Many studies that have been conducted demonstrating the benefits of these teaching tools often have methodological limitations (e.g., small sample size, no random assignment of subjects). Further research, pilot studies, demonstration projects, and/or subject matter expert consultations are needed to identify the optimal applications of these technological learning approaches in a driver education context. Gen Alpha teens are digital learners, comfortable with technology, and expecting visual, interactive, hands-on, personalized learning experiences and will soon be enrolling in driver education. The NTDETAS have already incorporated teaching methods, strategies, and tools that have the capacity to satisfy Gen Alpha's specific learning styles. More focus should be directed at ensuring driver education programs and driving instructors are prepared to meet this generational transition of digital learners.

This white paper did not have the scope and capacity to address all research questions identified by members of ANSTSE and State driver education administrators. Only research questions identified as priority were addressed in this review. Additional research questions/issues in sections of the NTDETAS on parent involvement in driver education, training requirements to become a competent driving instructor, and driver licensing (e.g., graduated driver licensing) and testing for licensure through driver education, remain unanswered. These are important issues to tackle to fill information gaps and further improve the comprehensiveness and veracity of the NTDETAS.

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