Prävention von Verkehrsunfällen durch einen Situated-Cognition-Ansatz
im naturwissenschaftlichen Unterricht

Eine Design-Based-Research-Studie zur unterrichtlichen Nachbereitung des *Crash Kurs NRW*

I N A U G U R A L - D I S S E R T A T I O N
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vorgelegt von

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Die Fragen sind es, aus denen das, was bleibt, entsteht.
(Erich Kästner, 1899-1974, dt. Schriftsteller)

Zusammenfassung

Diese Dissertation untersucht verkehrssicherheitsrelevante Fragestellungen unter dem Aspekt der Reaktanzbildung, mit dem Ziel, den Perspektivwechsel vom Lernenden zum Lehrenden zu vollziehen und dabei sowohl empirische als auch theoretische Ansätze zu integrieren.

Studie 1 befasst sich mit der emotionalen Wirkung von Verkehrssicherheitskampagnen und der Notwendigkeit einer gezielten Nachbereitung, um Reaktanz zu vermeiden. Die Studie zeigt, dass emotionalisierende Präventionsprogramme wie der "Crash Kurs NRW" bei Schüler*innen starke emotionale Reaktionen hervorrufen können, die ohne geeignete Nachbereitung zu widersprüchlichem Verhalten führen können. Durch die Implementierung strukturierter Nachbereitungsmaßnahmen, die unter anderem Methoden der kognitiven Verhaltenstherapie nutzen, konnten Wissenslücken und reaktantes Verhalten erfolgreich adressiert werden. Die Ergebnisse deuten darauf hin, dass eine solche Nachbereitung entscheidend ist, um die Wirksamkeit von Verkehrssicherheitskampagnen zu erhöhen und langfristige Verhaltensänderungen zu fördern.

Studie 2 untersucht die Wirksamkeit von vergleichbaren Verkehrssicherheitsprogrammen zu „Crash Kurs NRW“, die emotionale Appelle und physikalische Prinzipien kombinieren, um sicherheitsgerechtes Verhalten zu fördern. Die Teilnehmer*innen beschäftigten sich zusätzlich zum Nachbereitungskonzept aus **Studie 1** mit realistischen Unfallfolgen anhand eines Unfallautos als Exponat, um beispielsweise die Auswirkungen von überhöhten Geschwindigkeiten zu veranschaulichen. Die Studie bestätigt, dass die Kombination von emotionalen Appellen mit lösungsorientierten und handlungsorientierten Maßnahmen geeignet ist, um Reaktanz zu minimieren. Besonders hervorzuheben ist, dass solche Kampagnen nicht nur zur Förderung von Verkehrssicherheit, sondern auch zur anschaulichen Gestaltung des Physikunterrichts hervorragend geeignet sind. Durch die direkte Verknüpfung von theoretischen physikalischen Konzepten mit praktischen, realitätsnahen Szenarien wird das Verständnis der Schüler*innen für die Anwendung von Physik im Alltag vertieft. Der strukturierte Ansatz zur Nachbereitung solcher Kampagnen erwies sich als effektiv, um die durch die emotionale Ansprache ausgelösten Verhaltensmuster positiv zu beeinflussen. Diese Erkenntnisse legen nahe, dass Bildungseinrichtungen maßgeschneiderte Maßnahmen entwickeln sollten, um die Effekte von emotional aufgeladenen Präventionskampagnen zu verstärken und gleichzeitig den Physikunterricht durch lebensnahe Beispiele zu bereichern.

Studie 3 stellt einen innovativen Ansatz zur Lehre der Verkehrsphysik vor, der auf eine präventive Verkehrssicherheitsarbeit abzielt. Dieser Ansatz spiegelt die Erkenntnisse aus **Studie 2** und wechselt die Perspektive von den nur Lernenden auf die auch zukünftig

Lehrenden: er integriert theoretische Konzepte der Verkehrsphysik mit realen Verkehrssituationen und nutzt qualitative Forschungsmethoden wie Design Thinking und Interviews, um tiefere Einblicke in die Erfahrungen von Verkehrsteilnehmer*innen zu gewinnen. Studierende führten Verkehrsraumanalysen durch, identifizierten Gefahrenpunkte und entwickelten Prototypen, um praktische Lösungen für die Verbesserung der Verkehrssicherheit zu schaffen. Diese Prototypen reichten von der Optimierung von Verkehrsschildern bis hin zu technologiegestützten Sicherheitslösungen. Zusätzlich wurde ein Bewertungsinstrument für Modulprüfungen entwickelt, um die Objektivität und Qualität der Beurteilungen sicherzustellen. Der Ansatz förderte eine ganzheitliche Betrachtung der Verkehrssicherheit und betonte die Bedeutung präventiver Maßnahmen im Verkehrsumfeld.

Insgesamt unterstreichen die drei Publikationen die Notwendigkeit von interdisziplinären Ansätzen in der Verkehrserziehung, die emotionale, kognitive und verhaltensorientierte Elemente kombinieren, um langfristige Sicherheitskompetenzen zu fördern. Die Forschung zeigt, dass strukturierte Nachbereitung, praktische Anwendung und Empathie fördernde Methoden entscheidend sind, um reaktantes Verhalten zu reduzieren und die Wirksamkeit von Verkehrssicherheitsprogrammen zu maximieren.

Abstract

This dissertation examines traffic safety-related issues from the perspective of reactance formation, with the aim of transitioning from the learner's perspective to that of the educator, while integrating both empirical and theoretical approaches.

Study 1 focuses on the emotional impact of traffic safety campaigns and the need for targeted follow-up training to avoid reactance. The study demonstrates that emotionally charged prevention programs, such as the "Crash Kurs NRW," can evoke strong emotional reactions among students, which, without appropriate follow-up training, may lead to contradictory behavior. By implementing structured follow-up training measures, including cognitive behavioral therapy methods, knowledge gaps and reactive behaviors were successfully addressed. The results suggest that such follow-up training is crucial to enhance the effectiveness of traffic safety campaigns and to promote long-term behavioral change.

Study 2 investigates the effectiveness of comparable traffic safety programs to "Crash Kurs NRW," which combine emotional appeals and physical principles to promote safe behavior. In addition to the follow-up training concept from **Study 1**, participants engaged with realistic accident outcomes using a crashed car exhibit to illustrate the consequences of excessive speeds. The study confirms that the combination of emotional appeals with solution-oriented and action-oriented measures is necessary to prevent reactance. Notably, such campaigns are not only well-suited to promoting traffic safety but also to enriching physics education. By directly linking theoretical physics concepts with practical, real-life scenarios, students' understanding of the application of physics in everyday life is deepened. The structured follow-up training approach to these campaigns proved effective in positively influencing behavior patterns triggered by emotional appeals. These findings suggest that educational institutions should develop tailored measures to amplify the effects of emotionally charged prevention campaigns while also enhancing physics education through real-life examples.

Study 3 presents an innovative approach to teaching traffic physics, aimed at preventive traffic safety education. This approach reflects the insights from **Study 2** and shifts the perspective from mere learners to future educators: it integrates theoretical concepts of traffic physics with real traffic situations and employs qualitative research methods such as design thinking and interviews to gain deeper insights into the experiences of traffic participants. Students conduct traffic space analyses, identify danger spots, and develop prototypes to create practical solutions for improving traffic safety. These prototypes range from optimizing traffic signs to technology-based safety solutions. Additionally, an assessment tool for module exams was developed to ensure the objectivity and quality of evaluations. The approach promotes a

holistic view of traffic safety and emphasizes the importance of preventive measures in the traffic environment.

Overall, the three publications underscore the need for interdisciplinary approaches in traffic education that combine emotional, cognitive, and behavior-oriented elements to foster long-term safety competencies. The research demonstrates that structured follow-up training, practical application, and empathy-promoting methods are crucial in reducing reactant behavior and maximizing the effectiveness of traffic safety programs.

1. Übergreifende Einleitung

1.1 Relevanz des Themas

Mobilität steht für wirtschaftliches Wachstum sowie Teilhabe jedes Einzelnen am gesellschaftlichen Leben. Insbesondere für junge Menschen hat Mobilität in der Phase der Ablösung vom Elternhaus und der Vernetzung mit der Peergroup eine wichtige Bedeutung (Bastian T., 2010, S. 24). Nachweisliche Folgen der mobil-vernetzten Welt sind jedoch auch negativer Art: Pro Jahr sterben weltweit 400.000 junge Menschen zwischen 15 und 29 Jahren bei Unfällen im Straßenverkehr (https://www.allianz.com/de/presse/news/engagement/gesellschaft/141029-allianz-zur-sicherheit-im-strassenverkehr.html).

Verkehrsunfallpräventions- und Sicherheitsarbeit genießen daher eine hohe gesellschaftliche Aufmerksamkeit. Bei den Präventionsstrategien werden universelle bevölkerungsbezogene flächendeckende Maßnahmen von zielgruppenspezifischen Maßnahmen unterschieden, die sich durch soziodemografische Merkmale oder ihren Risikostatus definieren (Thapa-Görder, N., Voigt-Radloff, S., 2010). In Ländern mit niedrigem Einkommen ist die Zahl der Unfalltoten wesentlich höher aufgrund von Faktoren wie fahrzeug- und infrastrukturbezogene Gegebenheiten sowie mangelhafte Verkehrsmanagementsysteme (Faus M. Alonso, F. Fernández C., Useche S. A., 2021). Zudem beeinträchtigen in Schwellenländern Parameter wie die Abhängigkeit von staatlicher Finanzierung, fragmentierte Entscheidungsprozesse und geringe institutionelle Kapazitäten die Verkehrssicherheitsarbeit (Eusofe Z., Evdorides H., 2017).

Zu den Hochrisikogruppen gehören insbesondere junge Fahrer*innen in der Lebensphase des Erwachsenwerdens. Diese Phase ist geprägt von der Ablösung vom Elternhaus, der Suche nach Identität, prägenden Veränderungen der sozialen Beziehungen und der Orientierung an der Peergroup (Raithel J., 2011). Das Austesten eigener Grenzen ist typisch für diese Entwicklungsphase, die oft mit dem Erwerb des Führerscheins und einem größeren Zugang zu individueller Mobilität einhergeht. Weitere Ursachen für eine hohe Beteiligung am Unfallgeschehen liegen in den Kriterien „Anfängerrisiko“ und „Jugendlichkeitsrisiko“ (https://www.verkehrswacht-mv.de/angebote/junge-Fahrer*innen-Fahrer*inneninnen 09.09.2022).

Den Fahranfänger*innen fehlt oft die Erfahrung im Umgang mit Kraftfahrzeugen und Verkehrssituationen. Riskantes Verhalten in gefährlichen Situationen wird akzeptiert und das Auto wird zum Freiheitssymbol, das zur Bestätigung der Unabhängigkeit genutzt wird (Bastian T., 2010). Diese Risikoakzeptanz beeinflusst die Einschätzung der Gefährlichkeit und führt zu einem erhöhten Gefährdungspotenzial im Straßenverkehr (Seifert A., 2007; https://www.verkehrswacht-mv.de/angebote/junge-fahrer-fahrerinnen).

Jugendliche nutzen den Verkehrsraum auch als Sport- und Kommunikationsraum sowie als Treffpunkt für Gruppenaktivitäten. In der Peergroup werden wichtige soziale Funktionen gesteuert und riskante Verhaltensweisen finden oft Akzeptanz und Anerkennung (Limbourg et al., 2013). Zweck und Art der Verkehrsteilnahme definieren unterschiedliche Gefährdungspotenziale (Limbourg et al., 2013). Geschwindigkeitsverstöße, fehlender Abstand, Fahren unter Alkohol- und Drogeneinfluss, Fehler beim Überholen, Rotlichtverstöße und Ablenkung durch Handys sind häufige Unfallursachen bei jungen Fahrer*innen. Hinzu kommt oft das Nichtanschnallen, was das Verletzungsrisiko erhöht (www.destatis.de).
Verkehrssicherheitsarbeit muss zielgruppenspezifisch und methodisch selektiert auf diese Problematik abzielen. Hochrisikostrategien sind meist von höherer Kosteneffektivität als bevölkerungsbezogene Strategien (Thapa-Görder N., Voigt-Radloff, S. 2010). Neben ökonomischen Anreiz- und Bestrafungssystemen stehen edukative Verfahren im Vordergrund, die in Bildungseinrichtungen implementiert und umgesetzt werden (Thapa-Görder N., Voigt-Radloff S., 2010).
Ein innovativer Ansatz zur Verkehrserziehung ist die Einbindung eines Unfallautos als praktisches Lehrmittel. Das Unfallauto dient als anschauliches Beispiel, um die physischen und emotionalen Dimensionen von Verkehrsunfällen zu verdeutlichen. Die Teilnehmer*innen können die Verformungen, die durch überhöhte Geschwindigkeit verursacht wurden, direkt untersuchen und die physikalischen Prinzipien dahinter verstehen. Diese Methode hat gezeigt, dass sie weniger Reaktanz erzeugt und effektiver zur Verhaltensänderung beiträgt als traditionelle Bühnenkampagnen wie der Crash Kurs NRW allein (von Beesten S., Bresges A., Lubert, D., 2024). Ein Unfallwagen kann auch im naturwissenschaftlichen Unterricht genutzt werden, um kinematische Variablen bei einer Kollision zu erklären und so physikalische Konzepte im Zusammenhang mit Verkehrssicherheit anschaulich zu vermitteln (von Beesten S., Bresges A., Lubert, D., 2024).

1.2 Zielsetzung der Dissertation

Die Zielsetzung dieser Dissertation ist es, durch eine umfassende und methodisch fundierte Analyse der Verkehrssicherheitsarbeit innovative Ansätze zur Prävention und Ausbildung zukünftiger Lehrkräfte zu entwickeln und zu evaluieren.

1.3 Forschungsfragen

Diese Dissertation untersuchte folgende übergreifende Forschungsfragen:

1. **Studie 1:** Welche didaktischen Methoden und inhaltlichen Gestaltungselemente sind geeignet, um durch sie die Minimierung von Reaktanz und die Förderung von Empathie sicherheitsrelevante Botschaften aus verkehrspädagogischen Bühnenveranstaltungen

nachhaltig zu vermitteln und das Risikoverhalten der Teilnehmer positiv zu beeinflussen?

2. **Studie 2:** Wie wirkt sich das veränderte Konzept eines Unfallauto-Exponats auf die Reaktanz der Teilnehmer aus, und welche Rolle spielen die Anwesenheit der Polizei, die unterrichtliche Nachbereitung sowie die Eignung des Exponats zur Vermittlung physikalischer Themen in Bezug auf die Förderung einer nachhaltigen Verhaltensänderung?
3. **Studie 3:** Wie wirkt sich die Integration des Moduls "Verkehrsphysik" in die Lehramtsausbildung auf das Verhalten und die Einstellungen angehender Lehrkräfte im Straßenverkehr aus, und welche Kriterien können zur praktikablen Anwendung des Design-Thinking-Ansatzes sowie zur Entwicklung eines Erwartungshorizonts für die Bewertung von Modulabschlussprüfungen im Bereich Verkehrsraumanalyse identifiziert werden?

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2. Methodik und Ansätze

2.1 Emotionale Appelle und deren Reaktanzreduktion

Zunächst wurden emotionale Appelle eingesetzt, um Teilnehmer*innen für die Folgen von Verkehrsunfällen zu sensibilisieren und ein sicherheitsbewusstes Verhalten zu fördern. Diese emotional aufgeladenen Präventionskampagnen wurden durch gezielte Maßnahmen ergänzt, um Reaktanz zu vermindern und sicherheitsgerechtes Verhalten zu fördern. Zu diesen Maßnahmen gehörten lösungsorientierte, handlungsorientierte und selbstwertsteigernde Interventionen, die Elemente der kognitiven Verhaltenstherapie und etablierter Verkehrssicherheitsprogramme integrierten (von Beesten S., Bresges A., 2022). Emotionale Appelle können jedoch auch zu Reaktanz führen, was die Effektivität solcher Kampagnen beeinträchtigen kann (Witte K., Allen M., 2000). Dieser vielseitige Ansatz zielte darauf ab, eine tiefere emotionale Verbindung und Verpflichtung zur Verkehrssicherheit bei den Teilnehmer*innen zu fördern.

2.2 Praktische Demonstrationen mit einem Unfallfahrzeug

Ein wichtiger Aspekt der Methodik war der Einsatz eines beschädigten Fahrzeugs als praktisches Lehrmittel. Die Teilnehmer*innen setzten sich intensiv mit dem beschädigten Auto auseinander und diskutierten die Verformungen, die durch überhöhte Geschwindigkeit verursacht wurden. Diese praktische Erfahrung sollte ein plastisches Verständnis für die physischen Konsequenzen von Verkehrsunfällen vermitteln. Zusätzlich nahmen die

Teilnehmer*innen an Rollensimulationen teil, in denen sie sich riskante Verkehrsszenarien vorstellten und Lösungen entwickelten. (von Beesten S., Bresges A., Lubert, D. 2024).

2.3 Verkehrsraumanalyse und Design-Thinking-Prozess

Ein weiterer zentraler Bestandteil der Methodik war die Verkehrsraumanalyse, bei der angehende Lehrkräfte aktiv in die Identifizierung, Analyse und Lösung von Verkehrsproblemen einbezogen wurden. Diese Analyse wurde durch die Anwendung des Design Thinking-Ansatzes unterstützt. Design Thinking fördert ein tiefes Verständnis für die Perspektiven, Bedürfnisse und Sorgen der Verkehrsteilnehmer*innen durch qualitative Forschungsmethoden wie Interviews und empathische Beobachtungen. Die Studierenden führten Interviews mit Fußgänger*innen, Radfahrer*innen und Autofahrer*innen durch, um die emotionalen und psychologischen Aspekte der Verkehrsteilnahme zu verstehen. Die gewonnenen qualitativen Daten aus den Interviews bildeten eine solide Grundlage für die weitere Analyse und Gestaltung präventiver Maßnahmen. (von Beesten S., Bresges A. 2024)

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3. Darstellung der Ergebnisse

3.1 Ergebnisse der Studien

3.1.1 Studie zur Nachbereitung der Bühnenkampagne „Crash Kurs NRW“

Die erste Studie zeigte signifikante Wissensgewinne und Veränderungen im Sozialverhalten der Teilnehmer*innen durch die strukturierte Nachbereitung der "Crash Kurs NRW"-Kampagne. Sie ermöglichte eine erfolgreiche Aufarbeitung von Wissensdefiziten über Unfallursachen und -folgen, was zu einem verbesserten Verständnis der Risiken und zu einem sicherheitsbewussteren Verhalten im Straßenverkehr führte. Dadurch wurde auch das reaktante Verhalten, das durch die emotionalen Appelle der Kampagne initiiert wurde, effektiv vermindert.

Vor- und Nachbefragungen bestätigten das Auftreten von Reaktanz nach emotionalen Kampagnen. Die Teilnehmer*innen zeigten zunächst eine ablehnende Haltung gegenüber den Botschaften, die potenziell zu konträrem Verhalten hätte führen können. Durch die gezielte Nachbereitung, die lösungsorientierte, handlungsorientierte und selbstwertstärkende Maßnahmen umfasste, konnte diese Reaktanz deutlich reduziert werden. Die strukturierte Nachbereitung half den Teilnehmer*innen, die emotionalen Inhalte der Kampagne besser zu verarbeiten und in konstruktives Verständnis und Verhalten zu überführen (von Beesten S., Bresges A., 2022).

3.1.2 Studie zur Anwendung eines Unfallautos als Exponat

Das neue Konzept der zweiten Studie eines Unfallauto-Exponats wurde positiv aufgenommen und erzeugte weniger Reaktanz im Vergleich zum etablierten Crash Kurs NRW. Die strukturierte Nachbereitung nach dem Exponat zeigte klare Erfolge in der Reduktion von Reaktanz bei den Teilnehmer*innen. Das unterrichtliche Nachbereitungskonzept erwies sich als effektiv bei der Förderung von sicherheitsbewusstem Verhalten, was zu einer nachhaltigen Verhaltensänderung führte. Zudem konnte das Unfallauto-Exponat erfolgreich genutzt werden, um physikalische Themen im Unterricht anschaulich zu vermitteln und zu erläutern (von Beesten S., Bresges A., Lubert D. 2024).

Ein überraschendes Ergebnis der Studie war, dass die Anwesenheit von Polizeibeamten keinen signifikanten Einfluss auf das reaktive Verhalten der Teilnehmer*innen hatte. Trotz der angenommenen Autorität und abschreckenden Wirkung der Polizei zeigte sich, dass ihre Präsenz in der Kampagne nicht dazu beitrug, das reaktive Verhalten der Teilnehmer*innen zu verstärken oder zu mindern. Dies unterstreicht die Bedeutung einer gut strukturierten und pädagogisch fundierten Nachbereitung, um die gewünschten Verhaltensänderungen zu erzielen, anstatt sich bei Kampagnen allein auf die Vermittlung von Botschaften durch Autoritätspersonen zu verlassen (von Beesten S., Bresges A., Lubert D. 2024).

3.1.3 Studie zur Entwicklung eines Moduls zur Ausbildung angehender Lehrender

Die dritte Studie präsentierte einen neuartigen Ansatz zur Lehre der Verkehrsphysik, der darauf abzielte, Unfälle durch eine ganzheitliche Herangehensweise zu verhindern. Umfangreiche Analysen, empirische Umfragen und die Entwicklung von Prototypen wurden genutzt, um Studierende aktiv in die Identifizierung, Analyse und Lösung von Verkehrsproblemen einzubeziehen, insbesondere im Hinblick auf die Sicherheit im öffentlichen Raum. Die Methodik dieses Ansatzes basierte auf der Anwendung theoretischer Konzepte der Verkehrsphysik in realen Verkehrssituationen. Schulen dienten als Testumgebungen, um bereits in einem frühen Stadium das Bewusstsein für Verkehrssicherheit zu schärfen. Studierende angehender Lehrämter, die sich zukünftig mit Verkehrssicherheitsarbeit als curriculares Kerngebiet beschäftigen sollten, führten Verkehrsraumanalysen durch, um potenzielle Gefahrenpunkte zu identifizieren. Dabei wurden Verkehrsdichte, Geschwindigkeitsmuster, menschliche Verhaltensabweichungen sowie Gesetzeskonformität untersucht (von Beesten S., Bresges, A. 2024).

3.2 Publikation von drei peer-reviewed Fachartikeln

3.2.1 Wirksamkeit der Verkehrssicherheitsprävention in Schulen

Einleitung: Die Weltgesundheitsorganisation schätzt, dass jährlich 13 Millionen Menschen weltweit bei Verkehrsunfällen sterben und über 50 Millionen verletzt werden. Eine Studie des Allianz Zentrums für Technik verdeutlicht, dass Verkehrsunfälle die führende Todesursache bei jungen Menschen zwischen 15 und 29 Jahren sind, mit etwa 400.000 Todesfällen pro Jahr (Allianz Zentrum für Technik, 2022).

Methoden: Weltweite Kampagnen zur Verkehrsunfallprävention setzen auf emotionale Appelle, um Autofahrer*innen zu sicherem Fahrverhalten zu motivieren. Die Forschung legt nahe, dass diese Appelle durch lösungsorientierte, handlungsorientierte und selbstwertstärkende Maßnahmen ergänzt werden müssen, um Wirksamkeit zu steigern und Widerstand zu vermeiden. Schulen benötigen gezielte Nachbereitung, um die emotionalen Effekte von Präventionskampagnen zu bewältigen. Das Nachbereitungskonzept zur Kampagne „Crash Kurs NRW“ beinhaltet Rollensimulationen, das Lösen riskanter Verkehrsszenarien und eine Übung zur Selbstwahrnehmung im Kontext der Einwirkung berauschender Mittel. Weiterhin bedachten die Studie den möglichen Bumerangeffekt übermäßiger Furchtappelle. (von Beesten S., Bresges A., 2022)

Fazit: Eine Fallstudie zum Nachbereitungskonzept des Crash Kurs NRW, einem Präventionsprogramm für Schüler*innen der Oberstufe, zeigt, dass sowohl simulierte Erlebnisse als auch Diskussionen über riskante Verkehrssituationen zu einem signifikanten Wissensgewinn führten. Dokumentiert wurden Veränderungen im Sozialverhalten sowie in Normen, Werten und Einstellungen der Teilnehmer*innen.

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Effectiveness of road safety prevention in schools

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The World Health Organization estimates that each year, 1.3 million people are killed and more than 50 million people worldwide are injured in road traffic accidents. According to a study conducted by the Allianz Center for Technology, more young people between the ages of 15 and 29 die in traffic accidents than as a result of illness, drugs, suicide, violence, or war events worldwide. That is about 400,000 per year, globally. Worldwide traffic accident prevention campaigns demonstrate the consequences of traffic accidents in an emotionalizing way in order to encourage drivers to adopt conscious safety behavior *via* adequate driving behavior. The consequences of traffic accidents are demonstrated by prevention campaigns often in an emotionalizing way to encourage drivers to adopt safety measurements through adequate driving behavior. Prior research suggests that the emotionalizing effect of the appeals must be accompanied by solution- as well as action-oriented and self-confidence-increasing measures, so that the instructive message is reinforced and does not lead to reactance. Thus, a strong need arose in the schools for a targeted training as the follow-up of emotional prevention campaigns. A suitable training for knowledge acquisition and knowledge transfer into everyday life was developed by means of the design-based research method. To create the targeted follow-up, various methods from cognitive behavioral therapy and common traffic safety programs were adapted. This publication is dedicated to a first explorative research approach in a non-standardized form of a social training. It approaches the question of negative emotional states immediately after a *Crash Kurs NRW* stage event, which is a prevention program in Germany that targets upper middle school and high school courses and originates from North Rhine-Westphalia. Changes in social behavior and development of participants' own norms, values, and attitudes were observed and documented and are discussed and presented in this article. The result of the survey confirmed prior research and showed visible effects of reactance after the Crash Curs NRW campaign. It was found that a structured follow-up training is suitable to gain reactive behavior from the stage event. Knowledge deficits about the cause and outcome of accidents were successfully addressed in the follow-up. This may have influence the reactance behavior and could be a key factor for successful prevention campaigns. Further publications will observe the connection between knowledge and reactance in subsequent iterative passes of modified follow-ups for the Crash Course NRW Campaign.

KEYWORDS

road safety, safety behavior, design-based research, youth risk, road accident prevention

Introduction

Mobility stands for economic growth and the participation of each individual in social life. It is particularly important for young, adolescent people in the phase of detachment from the parental home and networking with the peer group (Bastian, 2010, p. 24).

However, there is evidence that the mobility also has negative consequences: in total, 400,000 young people between the ages of 15 and 29 die each year in road traffic accidents worldwide (Allianz, 2014).

Consequently, traffic accident prevention and safety work enjoy a high level of social attention.

Prevention strategies are divided into universal, population-based, and area-based vs. target group-specific measures, which are declared, for example, by their sociodemographic characteristics or by their risk status (Thapa-Görder and Voigt-Radloff, 2010, p. 19). As a result of the causal relationship between vehicle and infrastructure-related factors and traffic management, the number of accidental deaths is much higher in low-income countries, for example (Faus et al., 2021a). In addition, especially in emerging countries, parameters such as the dependence of funding on government sources, fragmentation of decision-making processes in multidisciplinary areas, legal frameworks for road safety, public awareness, local needs, and institutional capacity for road accident prevention work are major determinants of advancing influential safety work (Eusofe and Evdorides, 2017).

Young drivers in the adult life phase are included in the high-risk group. The reasons for this classification are the detachment from the parental home, the search for identity, formative and groundbreaking changes in social relationships, orientation to the social peer group, and finding one's own social status. Testing one's own limits is typical and immanent in the adolescent phase of development.

For most young adults, this critical development phase includes the acquisition of a driver's license and, associated with this, greater access to individual mobility (Raithel, 2011, p. 9). Further causes for a high level of involvement in accidents lie in the additional criteria of "novice risk" and "youth risk" (Jugendlichkeitsrisiko, Landesverkehrswacht MV, www.verkehrswacht-mv.de, 18.06.2022). Novice drivers lack experience in dealing with motor vehicles and traffic situations. Risky behavior in dangerous situations is more likely to be accepted. As unsafe driving style develops, the car becomes a symbol of freedom (Bastian, 2010, p. 47).

This risk acceptance influences the assessment of the dangerousness and leads *via* incentives (cost-benefit) toward dangerous behavior (Seifert, 2007, p. 1), further in sum with the "beginner's risk" to an increased hazard potential in road traffic (Jugendlichkeitsrisiko, Landesverkehrswacht MV, www.verkehrswacht-mv.de, (18.06.2022).

Young people also use the traffic area as a sports and communication space and as a meeting place for group activities. Important social functions are controlled in the social reference group ("peer group"), where acceptance and recognition are also and especially found for risky behaviors. Consequently, age-typical dangerous behavior is to be seen as a main risk variable (Limbourg, 2013).

The purpose and type of traffic participation define different hazard potentials (Limbourg, 2013). Speeding violations, also combined with a lack of distance to the vehicle ahead, driving under the influence of alcohol or drugs, overtaking errors, red light violations and distractions, for example, by cell phones, lead the statistics for the causes of accidents among young drivers. Often, not wearing a seat belt is added as an injury-increasing criterion (www.destatis.de).

Therefore, road safety work must target this problem in a methodologically selective manner. These high-risk strategies are target group-oriented, but usually of higher cost-effectiveness than population-based strategies (Thapa-Görder and Voigt-Radloff, 2010, p. 19). In addition to penalty-based incentive and punishment systems, the focus is on the educational procedures (Thapa-Görder and Voigt-Radloff, 2010, p. 19). These are implemented and put into practice in educational institutions.

Theoretical framework

Prevention in the area of tension between practice and science

Cooperations among the police, local authorities, traffic guards, associations, and other institutions make it possible to communicate traffic accident prevention in a sustainable manner.

The police identify current traffic accident phenomena and hot spots, initiate prevention projects and, if necessary, participate in them (Verkehrssicherheitsarbeit der Polizei, https://www.recht.nrw.de, 06.09.2022). Police is present every day in the context of education and upbringing with its prevention work at educational institutions; indeed, it moves continuously and acts pedagogically in the areas of tension that arise from the encounter of pedagogical activities and core police work (Kepura, 2021, p. 278). Schools and the police encourage young people to become independent-minded, responsible personalities in the area of conflict between freedom and rules.

The school's educational mission should also convey the meaning of norms and reflect on them critically. Democracy-related educational goals such as autonomy, maturity, and the ability to participate and reflect are thus captured (Dewey, 2016).

Researching prevention work across systems (here: pedagogy and police) opens up greater perspectives of

knowledge than the theoretical framework of only one scientific discipline, because the knowledge generated then does not remain entrenched in the inherent logic of the respective system (Steffen, 2012, p. 40).

In addition, studies have shown that communication campaigns, related to road safety messages, can be significantly increased in the effectiveness when accompanied by traffic education activities (Faus et al., 2021b).

Behavior change through fear appeals

Road safety campaigns aim to change the behavior of their participants. Toward that goal, some campaigns aim at positive behavioral change in favor of health regularly act with the conception: "Create fear!".

The cognitive dissonance of the perhaps deadly, but fast car ride with fun factor, must be resolved in favor of future orientation for the individual.

Newly propagated behavior patterns are to be strengthened, and the old ones renounced (Bonfadelli and Friemel, 2010, p. 56).

If the fear appeal is too strong, it can result in reactance (Dahlgren, 2021, p. 153, Dillard and Shen, 2005, p. 144). When people are exposed to content they have not asked for, they may see that as a threat to their received freedom. They may restore their freedom by becoming angry and counterarguing, or in some cases by choosing actions consistent with their prior attitudes since forced exposure can "subjectively decrease the attractiveness of the imposed alternative and increase the attractiveness of the denied option" (Dahlgren, 2021, p. 153).

The recipient denies the threat but does not change his behavior as desired, or even behaves in the opposite direction. This is often referred to as the *"boomerang effect"* in social psychology (Rossmann and Hastall, 2019, p. 435).

As early as the 1960's and 1970's, theories were developed that dealt with behavioral change through punishment or fear (Rogers, 1975, p. 93–114). These *"fear appeal theories"* could not be empirically proven in their effectiveness (Ehlert, 2002).

According to the recent research, fear appeals are only effective if coping skills are promoted at the same time and action goals, action outcomes, and self-efficacy expectations are strengthened (Koehler et al., 2022, p. 3).

In addition, there is the finding that the effect of fear appeals is influenced by the individual differences in self-esteem (Leventhal and Hirschmann, 1982, p. 183–226).

The form and content of the formulated message are thus substantial, and the personal possibilities of the recipient determine how they are received. This determines the transport of content (Witte and Allen, 2020, p. 591–615).

First, the confrontation with the risk takes place, where the recipient first evaluates the risk. Positive and risk-minimizing behaviors are also presented. If the risk is assessed as low, no further processing takes place, and the new behaviors are not considered further. If the risk is rated as high, two things can happen: If one's own self-efficacy is perceived as sufficient to counter the risk with the help of the presented new behaviors, then the new behaviors are adopted. If the risk is rated high, but one's own self-efficacy is rated too low, and the new behaviors are rated as not suitable, not feasible, or unrealistic, then the new behaviors would not adopted, but rather the risk would be denied.

The US-American Psychologist Martin Seligman described this state as that of "learned helplessness," which provides a suitable breeding ground for the development of, for example, depression and anxiety and thus in turn reduces self-worth (Seligman and Petermann, 2016).

Hackenfort et al. (2015, p. 215) therefore argue that a targeted follow-up is indispensable to implement traffic safety relevant behavior. This means that messages in themselves must be logical, comprehensible, and practicably applicable. Their meaning must be understood, and then, the new knowledge is readily applied.

This finding is supported by knowledge from health research studies on AIDS campaigns in the USA, which found that mass media campaigns as a prevention strategy can be successful in reducing AIDS under certain conditions and with careful planning and good execution, preferably with a focus on positive messages (Zatonski and Herbec, 2016).

In addition to these aforementioned criteria that influence readiness for behavior change, there is another important factor: recall of previously received safety messages at the right time in a traffic setting. A study of traffic safety behavior in the Dominican Republic focused on the human factor of remembering traffic safety campaigns with the result that only male professional drivers who had a driver's license and drove regularly were most likely to remember safety-related campaign messages (Faus et al., 2021b).

Thus, when these criteria are considered, the opportunities for effective road safety management increase.

Potential stress reactions

The presented knowledge about the mode of action of fear appeals and the fact that these effects anchor themselves in the thoughts and emotional world of the addressee leads to the implied question of what consequences these triggered emotions have through the use of confronting media.

The risk of psychological overload through the presentation of the emotionally overstraining elements of the stage event and the psychological disturbance patterns that could be triggered by this seems to be given.

Overloads according to ICD 10 are in particular:

- F43.0 Acute stress reaction – without disease value, but with the risk of decompensation and an associated malaise.

- F43.2 Adjustment disorder–with disease value.
- F43.1 Post-traumatic stress disorder–with illness value (www.icd-code.de/icd/code/F00-F99.html).

This requires the preparation of the schools, in which students in risk of a post-traumatic stress disorder are detected and excluded from the stage event.

Finally, a well-prepared follow-up is required in which the contents are finalized by specific options for action in order to strengthen the learned messages and to prevent the scientifically known negative consequences of the so-called fear appeals.

Research questions

Causally, the findings so far in this paper lead to the following key research questions:

Q1: Which didactic methods are suitable to extract and strengthen *the safety messages of the stage event?*
Q2: Which didactic methods are suitable to influence dangerous behavior in an empathy-expanding way?
Q3: How must a follow-up module be designed in terms of content in order to be able to attach important road safety messages in the long term?
Q4: Was reactive behavior generated by the Crash Course NRW stage event and could it be minimized through follow-up modules?

Materials and methods

Overview of the entire research

The design-based research method allows a systematic approach to these complex problems (Plattner et al., 2016).

We look at the problem through the user's lens.

In six different phases, the logic of the successive course of projects is measured against the milestones in order to drop or pass process steps if necessary.

Through iteration, the sequence of process steps through loops to previous phases. In this process, openness to results and a culture of mistakes are implemented: Because every failure, if recognized early, is a gain for the progress of the innovation process (Gerling and Gerling, 2018).

Initial design

Based on the complexity of a traffic accident prevention campaign in all schools of an entire federal state for students between 16 and 24 years of age, it seemed obvious to use the research design of the design-based research method. This design promised sufficient systematic structures to be able to capture the wealth of needs and still focus on the necessary goals and promote their further development. In this study, we conducted research accompanying a Crash Course prevention program specifically addressing young drivers and passengers in their peer group.

The stage event took place 1 week before the follow-up.

In the stage event, the police presents the course of the rescue chain with actors and affected people as well as the events at the scene of the accident in an informative way.

With emotional biographical reports and vivid pictures, police and fire department officers, paramedics, emergency doctors, emergency chaplains, or even relatives of accident victims report on the causes and consequences.

Personal experiences such as the scene of an accident, first aid, or the news of a death are included.

Together with the use of confronting media, strong emotions are triggered in the participants.

As a state campaign by the police of North Rhine-Westphalia in cooperation with educational institutions, the Crash Course NRW prevention program specifically targets young drivers and passengers in their peer group, aiming to convey the following statements:

- Traffic accidents have a cause and do not just happen.
- Traffic accidents are avoidable.
- Deliberately disregarding traffic rules is a main source of traffic accidents.
- Important traffic rules are as follows: control your speed, buckle up, do not drink and drive, and do not distract the driver (or let other distract you as a driver).

The Crash Course NRW state campaign is designed as a program with three phases, in which schools and the police work together.

The Figure 1 shows the three different phases with possible interventions to support proportionality and avert danger.

Methods

The aim of this exploratory study was to uncover how people construct their reality, how functional or dysfunctional this constructed reality is, and how it needs to be restructured in order to achieve traffic safety-relevant behavior. Through an explorative examination of the risks of road traffic in conjunction with the information obtained through one's own possible actions, derivations for a changed future-oriented behavior and thus also stimuli for the cognitive restructuring of one's own norms, values, and attitudes can be created (Kleebein et al., 2010, p. 19).

In a secondary school class in the *Rheinisch-Bergisch* district, with $n = 86$ students, the explorative method is applied in the

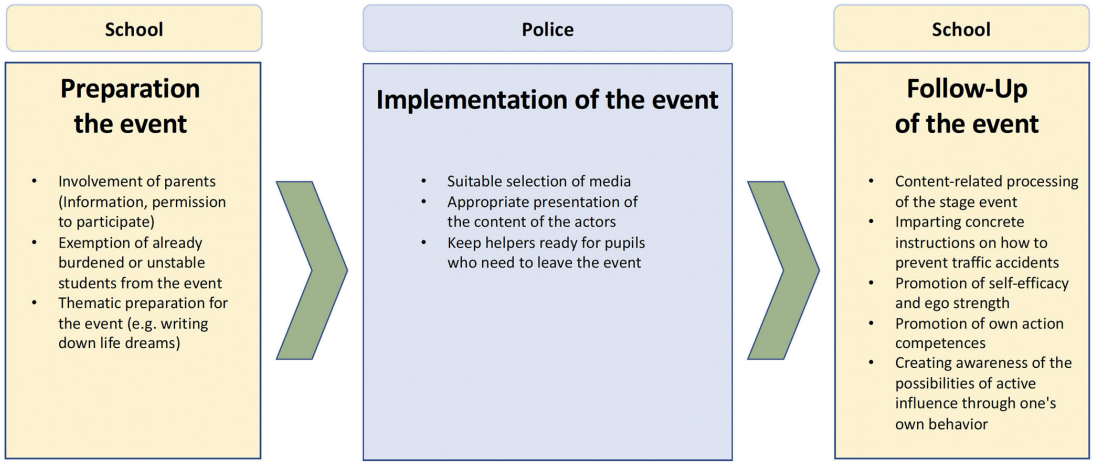


FIGURE 1
Overview of the phases of action of the Crash Kurs NRW.

form of social training in order to gain insight into initially unstructured situations.

Returning to the research questions, the categories in which they were applied and the methods used to inquire about them are outlined below:

Q1 and Q2: Evaluating didactic methods of self-reflection, cognitive restructuring, change of perspective, and emotional reassessment by field-testing a targeted follow-up training, including the exercises *"Risk Assessment,"* *"Alcohol Impairment Goggles Memory,"* and the role play *"The Last Two Minute."*

Q3: The main causes of accidents are discussed within a focus group.

This moderated and focused discussion enables the participants to debate on behavioral measures that, on the contrary, lead to traffic safety behavior instead of risky behavior.

Q4: Application of special questions in both a pretest and post-test, which give indications of reactance. In addition, during the event, we observed whether there were any corresponding derogatory remarks or dismissive behavior, e.g., increased cell phone use or conspicuous staring out the window.

The research survey was conducted exclusively with an online survey instrument.

The implementation of the intervention measure took place in the respective class in a familiar environment. In favor of the largest possible usable activity area, a circle of chairs with a centrally located open area was organized.

TABLE 1 Overview of disputation techniques from cognitive behavioral therapy according to Wills, 2014.

Logical disputation style (reveals contradictions within thinking)	Driving fast is fun and gives a feeling of freedom, but what are the consequences and are they also a guarantee of freedom?
Empirical disputation style (points out differences between reality and thought)	Is it just driving fast, which is fun, or can I do something else with the same effect but more safety?
Hedonistic disputation style (explains advantages and disadvantages of certain thought patterns)	Is speeding a suitable method of maintaining freedom in the long term? Does it also have disadvantages?

The risk assessment

By creating a risk assessment (see Appendix risk assessment) along a marked line between the poles "Dangerous" to "Harmless," the participants themselves define the subjective matter of danger and the dangerousness of different traffic situations and discuss them.

Participants then reviewed their assessment in class as well as in facilitated discourse and reassessed if necessary.

Individual maps or hazards have been picked up and repositioned again and again.

The pros and cons of hazard assessment as well as the presentation of the current legal situation regarding these maps formed the core of the accompanying moderation.

Guided discovery as a technique from cognitive behavioral therapy serves the cognitive restructuring. One's own view

of things and the perspective taken is then also reconsidered with the help of a Socratic dialog. Uncovering and moderated entanglement in contradictions make it clear that misbehavior in road traffic is without advantage and only seemingly logical. By creating confusion, distorted beliefs can be reframed and dysfunctional biases can be restructured into realistic assessments (Revenstorf and Burkhard, 2015, p. 256).

The view from the meta-level leads to the realization that the previous way of thinking is only one possibility among many and that other perspectives are just as realistic (Beck, 2013, p. 223 ff.) (Table 1).

As a result, a process of cognitive restructuring can be initiated and sustainably anchored in these exercises. The joint discovery in the peer group, guided by the facilitator, makes this possible (Figure 2).

The "fatal vision alcohol goggles"–memory

Police, Deutsche Verkehrswacht (German road safety organization), ADAC (General German Automobile Club), schools, and other institutions use *fatal vision alcohol goggles* at campaign days and driver safety training courses to warn against alcohol consumption. The fatal vision alcohol goggles can simulate different levels of intoxication, produce limited all-round vision, double vision, misjudgments for proximity and distances, confusion, tunnel vision, delayed reaction time, and the feeling of insecurity (see https://www.lwl.org/ks-download/downloads/TakeCare/Toolbox/additional_exercises/Rauschbrille_Drunk%20Buster_Germany.pdf, 08.09.2022). The simulation refers to the representation of some intoxication effects as they can be found with increasing blood alcohol concentration (BAC) in the literature (Just, 2020, p. 464).

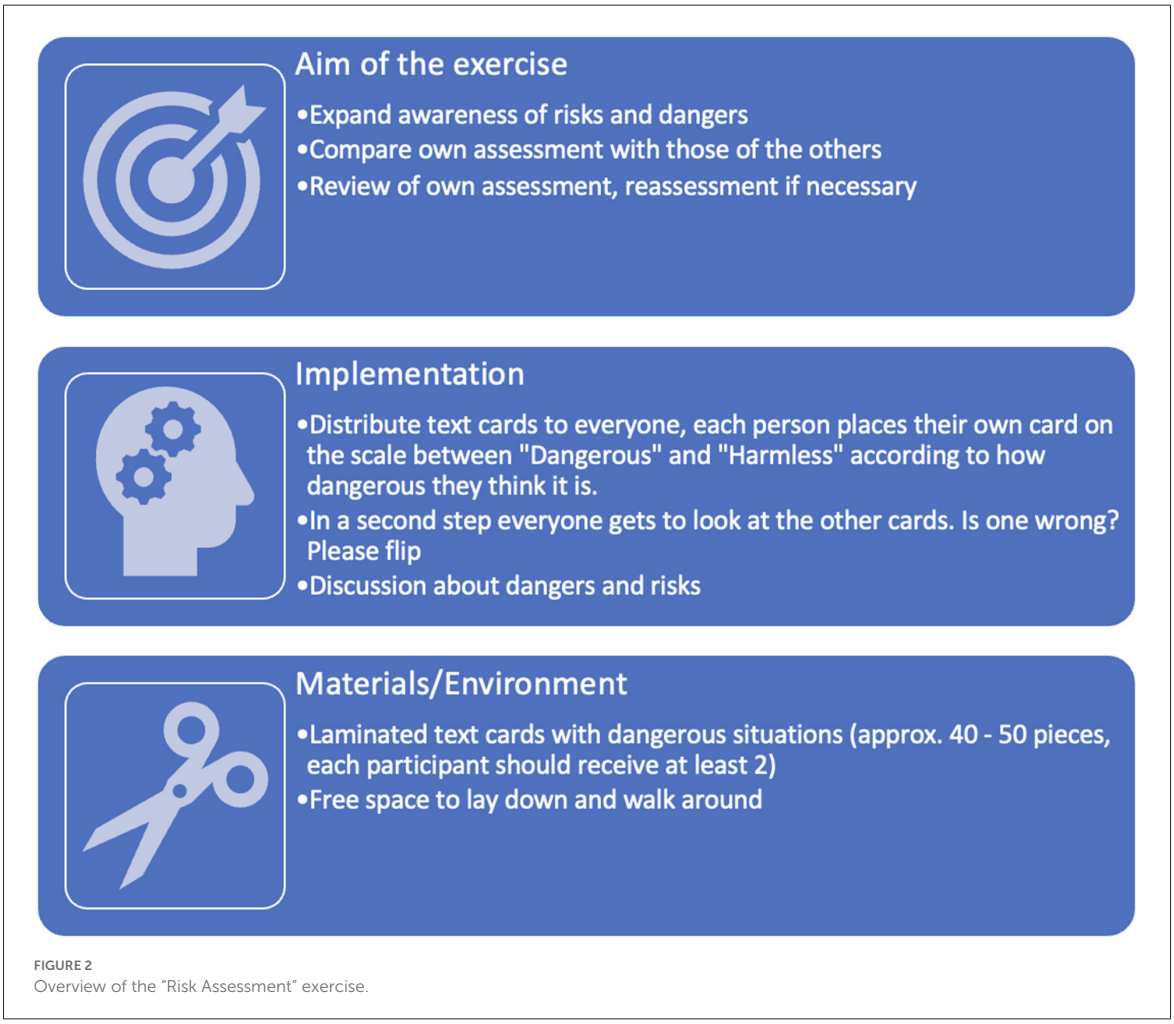


FIGURE 2
Overview of the "Risk Assessment" exercise.

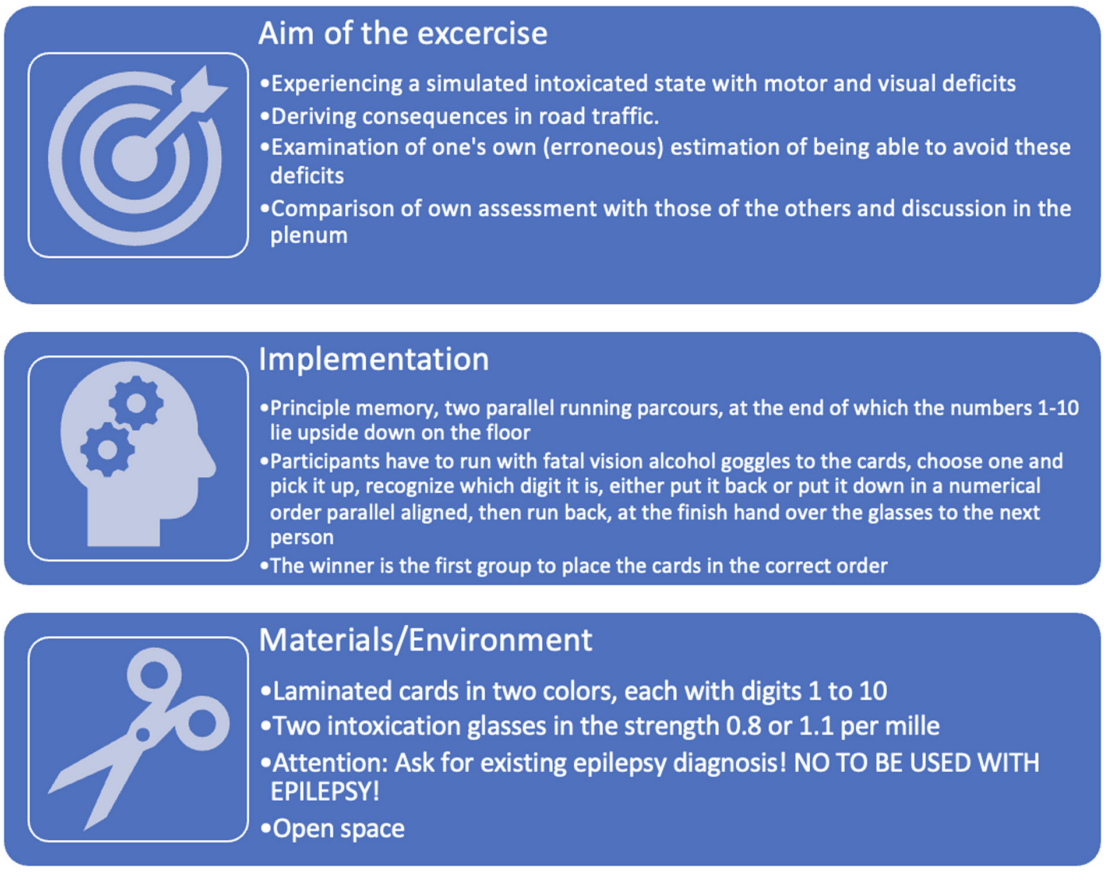


FIGURE 3
Overview of the "Fatal vision alcohol goggles" exercise.

Figure 3 shows the own experiences with the fatal vision alcohol goggles.

The effects observed in the exercise are used for a targeted evaluation and are used to check dysfunctional assumptions. In the exploration, an exchange of experiences about the effects of alcohol takes place, and legal basics and consequences are explained.

The role play "The last two minute"

Participants simulate a driving situation in which they can actively influence events through their own actions.

The typical causes of serious injuries in road traffic had been communicated to the participants through the previous exercises and were therefore familiar to them.

However, knowing something does not necessarily mean protecting oneself from it. Initiating a specific action requires more than just "*the desire to do it* and the *knowledge of how to do it*" (Weinert et al., 1987, p. 3), according to Heckhausen and Gollwitzer's "Rubicon model." Furthermore, it is necessary to be able to access behavior that has already been actively performed, which can then also be retrieved during stress.

The recall of an already known behavior, an already thought-out course of action, can also be possible in stress according to the theory of "*embodied cognition*" by Margaret Wilson. According to this theory, body, mind, and environment influence each other in thinking, feeling, and acting. Our thoughts trigger embodied reactions and *vice versa* (Wilson, 2002, p. 625). That means, any perception, both positive and negative, is stored as body memory with the corresponding physical attitude at that experienced moment. In the present role play, that would be the assumption, the experience at the time of the driving simulation, including the associated body posture and behavior, would be completely remembered in a later re-experience and could be reproduced as an automatism (Wilson, 2002, p. 634).

In this role play, students are asked to put themselves in the situation of being in a vehicle 2 min before a fatal crash. The social situation in the vehicle is presented to all the students by the following introduction:

Through a conversation with the parents of one of the people involved in the accident, we know that the couple in the front seats were arguing when they left the parents' house. Jan and Marc are best friends, and Marc would never publicly criticize Jan, even if he made a driving mistake. Steffi is in a particularly awkward position socially: she has only been dating Marc for 2 weeks and is being taken out for the first time by the group in the evening. If she speaks up critically, she risks making a bad impression.

Exercise assumption: all occupants of the car were killed in a collision at night with a roadside tree. (Source: https://crashkurs-nrw.uni-koeln.de/handeln-ueben, 08.09.2022). Role-playing builds up routines, behavioral sequences, and reactions. By trying out new behaviors, basic assumptions are changed, which in turn leads to new skills. Participants detect their own limits and weak points in critical situations and can work out solution scenarios (Beck, 2013, p. 257).

At the beginning, the role play offers a perspective transfer from the outside role to the influential driver and passenger role and puts the participants in the position of actively leading a car ride into disaster.

The deliberate bringing about of a catastrophe with a subsequent analysis of the risk factors should reveal the protection opportunities to the students that could have contributed to avoidance of the accident (Beck, 2013, p. 226–35).

Example: loud music distracted the driver. Derived protective behaviors: Turn down music in vehicle or turn it off altogether.

We use participant observation to explore whether this type of pedagogical role-playing is suitable for identifying risky actions in drivers. Furthermore, we test whether the co-drivers can recall and apply rehearsed actions to avert risky behavior under the simulated realistic conditions.

FIGURE 4
Overview of the exercise "The last two minute."

Intended Goal: Pedagogical role plays should enable recognition of dysfunctional actions and lead to more safety- and risk-conscious behavior by practicing modified functional actions. In Figure 4 the role play is presented.

In addition to the "Driving Situation" exercise, the following action strategies can be discussed:

- Where does a drunk passenger sit in the car? The result of the discussion should be: if possible, at the back on the right–furthest away from the driver under the supervision of others–without the possibility of directly influencing the driver and negatively affecting his or her driving actions.
- How can the passenger actively protect the driver? For example place arm on the backrest and separate the driver from the rear, observe what is happening in the car and intervene if necessary.
- Does loud music influence driving? Loud music influences concentration.
- What can I do as a passenger if I really want to get out of the vehicle? For example, feign nausea and vomiting.
- How do I deal with the situation if the driver is obviously unfit to drive before starting the journey? For example, take away the keys, call the police, do not get in the car myself.
- What options do I have for getting home safely if the scheduled driver drops out? For example, cab, calling parents or other friends, and public transportation.

Results

Results of quantitative methods

Results preliminary research

In order to capture the thematic needs of participants coming to the follow-up after a Crash Course stage event, an online survey of 86 participants was conducted 1 week after the stage event. The purpose was to clarify, prior to the intervention, which content-related questions remained unanswered among the target group after the stage event. Furthermore, the studies by Hackenfort suggest that reactance may already be present in some participants following the confronting stage event. The extent of this reactance should to be quantified with this survey. The survey conducted using the LimeSurvey® tool yielded the following results: 2020, secondary school grade 9, follow-up Crash Course NRW, $n = 86$ (complete responses: 71, dropouts: 6, did not participate in electronic survey: 9). Out of this 71:

- Twenty-two participants (31%) were taking part in the "Accompanied driving from 17" program at the time of the survey.
- Fifty-two participants (73%) felt sorry for the actors (SQ001).
- Sixty-seven participants (94%) wanted to prevent something like this from happening to them too (SQ002).
- Fourteen participants (20%) did not know at all/not at all that accidents can have these consequences (SQ003).
- One participant (1,5%) was "fully afraid"/5 participants (7,5%) were "rather afraid" to drive a car themselves (SQ004).
- Fifty-five participants (77%) found it important to talk about traffic accidents (SQ009).
- Forty-one participants (58%) already knew all this (SQ005).
- Fourteen participants (20%) were annoyed (SQ006).
- Ten participants (14%) would have preferred to go outside (SQ007).
- Forty-one participants (58%) will recommend the event to others (SQ008).
- Forty-two participants (60%) wanted causes of accidents to be addressed in follow-up (SQ001).
- Fifty-two participants (73%) wished that it was addressed how an accident can be prevented (SQ002).
- Fifty-one participants (71%) wished that it was addressed which situations are dangerous in road traffic (SQ003).
- Thirty-four participants (48%) wanted to know who takes care of the victims after a traffic accident (SQ004).
- Forty-six participants (65%) wanted to know more about legal conditions (SQ005).
- Forty participants (56%) wanted to learn more about the influence of health and traffic risk (SQ007).
- Forty-four participants (62%) wanted to know exactly what alcohol, drugs and medication do (SQ006).
- Two participants (10 %) indicated that they had no interest in follow-up at all (SQ008).

Results of the post-test

After the follow-up training, a quantitative survey was again conducted using the survey tool (2020, secondary school class 9, follow-up Crash Course NRW, $n = 86$ (fully answered: 57, dropouts: 15, did not participate in the electronic survey: 14). Out of this 57:

- Thirty-four participants (59%) consider distraction to be a dangerous risk factor (SQ001).
- Thirty-four participants (59%) consider alcohol to be a dangerous risk factor (SQ009).
- Thirty-four participants (59%) consider drugs to be a dangerous risk factor (SQ010).
- Thirty participants (52%) consider speeding to be a dangerous risk factor (SQ011).
- Thirty-four participants (59%) consider not wearing a seat belt to be a dangerous risk factor (SQ012).
- Thirty-six participants (63%) consider running a red light to be a dangerous risk factor (SQ013).

- Thirty-one participants (54%) also consider the passenger to be responsible for preventing an accident (SQ008).
- Twenty-one participants (37%) consider drinking a little alcohol to be harmless (SQ006).
- Fifteen participants (26%) are often told by others to be more careful (SQ003).
- Twenty-two participants (38%) feel safer now because they know more than they did before (SQ001).
- Fifteen participants (26%) see more potential for change in themselves (SQ004).
- Eighteen participants (31%) have a desire to change (SQ005).
- Five participants (8%) would like to try something risky now more than ever (SQ007).

In contrast to the preliminary research, which took place in class during the lesson time, the post-test was given to the participants during the break. This explains the lower participation average.

Through the results of the post-test it could be recognized that the knowledge needs of the participants could be taken up and adequately processed. The application of the training tools was able to trigger the personal development of the participants with regard to a more differentiated way of thinking in relation to their own risk behavior vs. their own safety behavior in road traffic, in order to critically reflect on and review their own behavior.

Results risk assessment

The situations depicted on the cards describe risky situations from everyday life, which in some cases result in fines and in many cases have been the cause of traffic accidents in recent years.

The participants were given the opportunity to rate the risk situations on a danger scale between "Dangerous" and "Harmless." The following graphics show a comparison of the personal assessment of the dangerousness of the situations in relation to the real statistical dangerousness and the classification of the remoteness or closeness to reality on the basis of some exemplary examples.

For the purpose of visualization, the traffic-relevant situational parameters were assigned weighting factors according to their danger levels. Harmless corresponded to weighting factor = 0, medium danger range to weighting factor =1, high-risk to weighting factor =2. The number of cards filed was multiplied by this weighting factor to determine the danger level.

In addition, the personally assessed dangerousness is compared with the real statistical dangerousness of the selected situations in the second graph. The overview in Figure 5 shows to what extent the personal estimation of danger corresponds to reality:

It can be seen that the risk of driving without a seat belt and being injured in an accident is rated highest by the participants. In fact, there is a lower risk here compared to the other causes of injury due to the high acceptance of wearing a seat belt in Germany. Compulsory seat belt use was introduced in Germany on January 1, 1976. At first, it applied only to the front seats, then in 1979 it was extended to the back seat. Through ongoing education campaigns, this road safety message seems to have become firmly embedded in the minds of participants.

Participants' assessment of the dangerousness of being able to cross the street as a pedestrian between cars coincides with statistical reality.

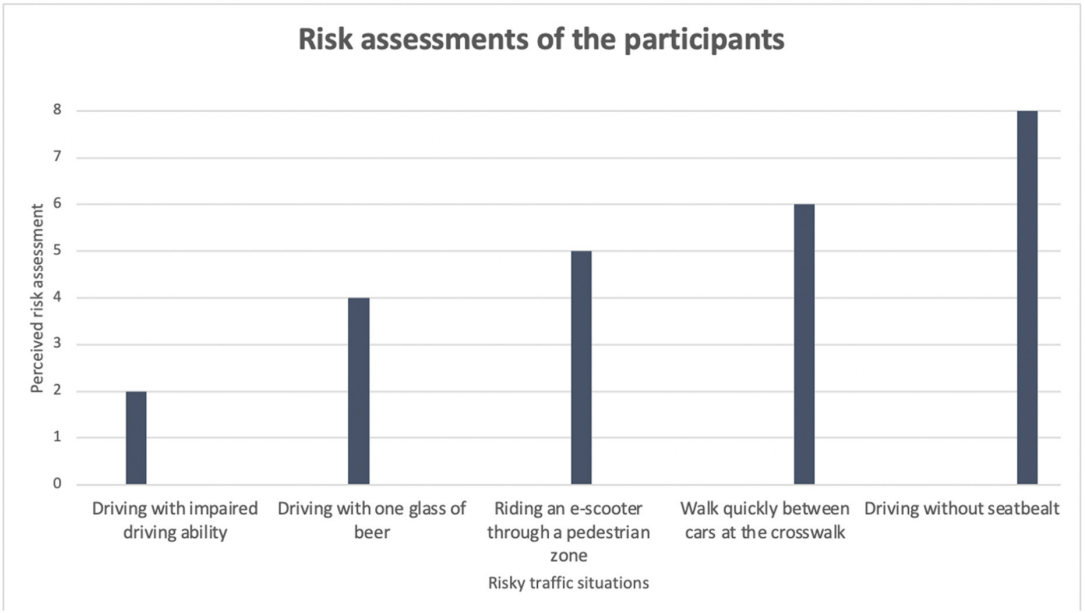
Participants perceive the dangerousness of e-scooters to be more risky than the statistical data indicates. One reason for this could be recent news coverage that distorts public perception regarding traffic accidents involving e-scooters (https://www.tagesschau.de/inland/e-scooter-unfaelle-101.html, 09/13/2022).

However, the participants' assessment of their fitness to drive under the influence of alcohol is estimated to be lower than the real statistical accident data shows. The above-mentioned risk of youthfulness could be a reason for this, as participants do not want to admit their own vulnerability in terms of physical reactions after alcohol consumption.

In addition to the level of risk, the situations described also expose dilemmas or raise moral questions. These are suitable for generating discussions on personal norms and values and for initiating changes of perspective.

Significantly striking was that the following risky situations were initially assessed as not dangerous:

- The pedestrian traffic light is just about to change to red, I quickly run across (misjudgement of the traffic rolling up again).
- I bought cabinets at furniture store and load them in the back seat (unsecured load).
- I only had one beer, I can still drive well with that (alcohol influence).
- With fever and headache, I drive quickly to the pharmacy (incorrect assessment of fitness to drive).
- I run across the tracks behind the train (fatal oncoming traffic, so-called "double strike").
- Riding a bicycle across the pedestrian walkway (risk of collision, pedestrian zone ban).
- I turn right and look very thoroughly and for a long time to the left to see if anyone is coming (traffic coming from the right is not noticed).
- As a pedestrian, I walk quickly between cars at the crosswalk (visual obstruction).
- I pull over on the right-hand side of the freeway because I feel sick (danger on the hard shoulder).



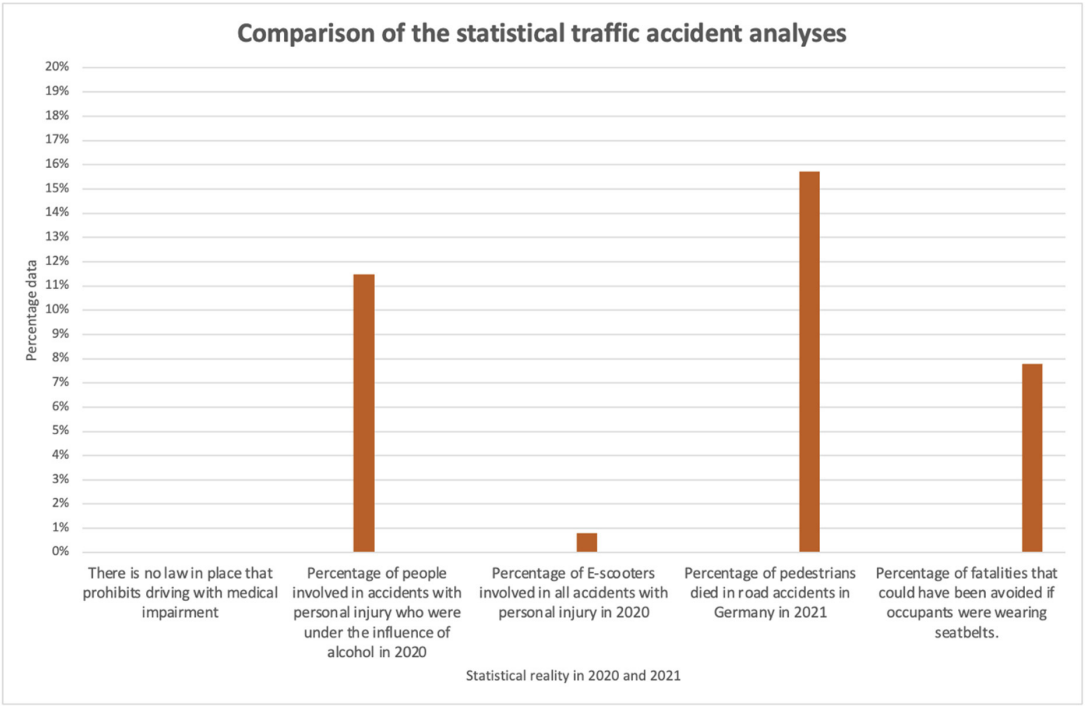


FIGURE 5
Results of the risk assessment, comparison of personal assessments and statistical reality, **(A)** represents the assessment of the participants, **(B)** represents the actual dangerousness.

- In a traffic jam I walk across the lane to see when it will go on (danger in the traffic rolling up again) Looking at the cell phone at a red light was only assigned to the medium risk area, although it corresponds to a fine offense according

to the fine catalog and can be punishable by points, which corresponds to the assignment of a risky behavior by the legislator and thus administrative injustice (see https://www.bussgeldkatalog.org/tatbestandskatalog-handy/).

An example of clarification of an unrecognized risky situation using Socratic dialog and cognitive restructuring can be found in the following documentation of Figure 6:

At the end of the discussion, no card was in the "Risk" range anymore. According to the post-test evaluation (post-test Appendix), these discussions led the students to new insights.

However, it also became clear that while the importance of the seat belt has received a high level of acceptance, more education is needed in the areas of alcohol, drugs, and general driving skills. In addition, there is still a need for more awareness of the subtle risk situations in bicycle, scooter, and pedestrian traffic.

In the evaluation of the risk scale, it turned out that the division into three risk areas is unfavorable for a scientific analysis. Therefore, in the next implementation, four fields will be taped off on the floor to create a Likert scale and to have the areas "Risk," "Rather Risk," "Rather harmless," and "Harmless" laid out.

Furthermore, it must be noted that a renewed comparison with the personal hazard assessment of the depicted situations on the cards after the discussion is missing. In a future research run, the participants should be asked again after the discussion to check their initially assigned hazard map with regard to the selected filing location and to re-sort it if necessary. This will allow any change in personal assessments of a hazard situation to be measurably tracked.

Moderator (M):	I see you are putting this card in the " no danger zone". Why?
Student (S):	Because I can do it quickly, I know the path well, it's automatic.
M:	Ah, ok, I see. Do you also go to school with a headache?
S:	No, absolutely not. I wouldn't be able to concentrate, there would be no point. I wouldn't be able to hear anything in class.
M:	Okay. So you say you wouldn't notice anything from the lessons, but the driving works automatically, right?
S:	Yes, exactly.
M:	Okay. What exactly do you have to do in class?
S:	Well, I have to sit here and listen and write something down now and then.
M:	Good. What would you have to do while driving?
S:	(thinking) I would have to pay attention to the traffic, to the traffic lights, to the road, to the pedestrians, I would have to park in front of the pharmacy. (Interjection from classmate: That alone is already mega exhausting).
M:	If you now list all of this yourself and compare it with each other, what seems more strenuous to you? Or in other words: Where would you have to concentrate more?
S:	Well, I think driving a car.
M:	Or asked another way: If you couldn't get something done at school because of the headache, what would happen at most?
S:	I would have to relearn everything, because I wouldn't have understood anything.
M:	Okay, that would be annoying. If you didn't get your act together while driving, what would be the worst that could happen?
S:	I could have an accident, the car would be broken or someone would be hurt or even dead.
M:	What would be worse for you? Relearning or someone would be dead?
S:	Yes, if someone were dead, of course!
M:	Yes, of course. That is, knowing what you know now, would you put the card somewhere else?
S:	(puts the card in the area "danger zone")

FIGURE 6
Documentation of a facilitated conversation role card.

Results of qualitative methods

Results fatal vision alcohol goggles

By means of field notes and observation protocols, the exercise with the intoxication glasses was researched *via* "Qualitative Observation." Observation is considered a classic method of qualitative social research. It forms the basis of all empirical research activity (Smart et al., 2013).

The product of the present observation was handwritten notes in class, which were followed by timely comprehensible transcripts on a personal computer.

The observations revealed how the course posed motor and visual difficulties for all participants. These are described in more detail below.

In the course:

- Walking movements deviating to the right or left along an imaginary line.
- Raising the legs when walking.
- Extremely slow walking.
- Extending the arms forward while walking.

When picking up and sorting the cards:

- Targeted grasping of the cards not possible (miss-grasping).
- Often wiping from the side or large area across the floor to grab the card.
- Holding the card alternately near and far in front of the eyes to recognize digit.
- Having to turn card to recognize digit.
- Need to ask group to know digit.
- Cannot place cards parallel.

The recognition as well as the numerical assignment of the digits in the correct order on the cards and a faultless passing of the way was connected with the alcohol-typical failure symptoms.

Initially, witty remarks by the surrounding other participants led to insecurity for the first participants.

Later, participants who had gone through the course became more serious and provided active support from the sidelines.

Serious uncertainty and fright resulted in remarks like, *"Gross, I wouldn't have thought that!"* or *"Oh my God, this is spooky!"*

The participants did not expect the altering effect of alcohol on body reactions and human perception in this form.

This was followed by a detailed discussion of the results, the communication of legal alcohol limits, and possible legal consequences. The effects on private life and the peer group were also included.

In the setting of the exercise *"The Last Two Minute,"* four classmates in the center of the room participated in a simulated car ride.

Results of the role play

The role player, who sat in the driver's position, was given a tablet with a pre-installed app. A game with a driving simulation was played on this during the role play. The idea was that the driver should do in the role play exactly what he would do in reality: he should steer a car over a road.

The car simulator on the tablet was a major distraction for both the classmates in the setting and the "bystanders." They approached the driver and watched him operate the app. The desired driving dynamics and the actual role play of the approaching accident did not occur. Getting into the role situation, "The last two minute before a fatal traffic accident" was unattractive and secondary compared to the game on the tablet. As a result, the author of the article (moderator) changed the moderation and interrupted the tablet car simulator.

In the sense of the design-based research approach, the next iterative step would be to project a car simulator to a larger screen, so that the audience can watch the simulation without approaching the driver.

Now, specific questions to the occupants of the simulation were used to establish the reference to the imminent traffic accident. Options for action, which could positively contribute to preventing such an accident, were to be developed.

Ideas were incorporated into the discussion using the brainstorming method; references to the real world, personal experiences, and hearsay experiences were taken into account. As a result, it was possible to develop the options for action that are suitable for everyday life for the age group.

Finally, it was asked whether the selected methods were suitable for conveying the contents and for bringing about clarification. The degree of suitability was determined by whether the method led to a gain in knowledge. The methods are presented in Table 2.

Discussion

Discussion of the project as a whole

About half of the class, including participants in the "Accompanied Driving from 17" program, participated very lively and attentively in the discussions and contributed their own thoughts. Another quarter of the participants responded well to specific questions, and the last quarter was rather quiet, but seemed to follow cognitively and participated in all the exercises.

This confirms the will to deal with the topics of road safety again in the follow-up to the experienced event. This is also reflected in the results of the post-survey in the actual knowledge gained.

In this first step, a very good overview of the beginning research could be gained. The research results of the impact evaluation, according to which content-related topics from the

TABLE 2 Overview of the evaluation of the applied methods, $n = 57$.

Method	Valuation	Knowledge gain
Danger scale with maps	15 participants now see road traffic with different eyes 28 participants got good information about the causes of accidents and risks in road traffic 23 participants found the situations depicted on the cards to be appropriate based on reality 14 participants had no previous knowledge about active participation in road traffic 30 participants did not find the exercise superfluous	Through the survey it could be deduced that the implementation of the event has brought a gain in knowledge for the participants in terms of road safety knowledge
Exercise with the noise goggles	37 participants learned about the effect of intoxication on the human body and the human psyche 32 participants did not find this exercise superfluous	A gain in knowledge about the effect of alcohol and the consequences in the context of participation in road traffic could be achieved
Exercise role play	32 participants said they now know how to be safer and more confident on the road, especially in the context of a peer group dynamic in the car and taking responsibility within a group. 26 participants did not find this exercise superfluous	A gain in knowledge about safety behavior in road traffic could be achieved

stage event should be taken up in the follow-up, could be seamlessly incorporated in their demands.

As a result, it is clear that the curricular follow-up of the Crash Course NRW stage event is important because otherwise questions and emotions could remain unanswered, which without clarification could lead to reactance.

This is confirmed by the preliminary survey, in which there is clear evidence of both open questions and emotions that led to reactive responses.

This became clear in the following: on the one hand, only 41 out of 77 participants stated that they would recommend the event to others, as well as 14 participants who answered that they were annoyed by the program. Here, due to the execution of the survey at the time *before* the follow-up with the knowledge about the dynamics of cognitive dissonance, an insecurity and lack of self-efficacy can be assumed. In this respect, the dynamics of the boomerang effect as a result of fear appeals may be considered here as an effect of the stage event.

In the post-test, the statement "*I'm going to try something reckless now*" (Appendix post-test) was used to investigate reactance again. In total, 5 participants indicated here that they would like to do this. This recorded less reactance than was assumed prior to the event. In connection to the result of 22 participants stating after the event that they knew more in terms of road safety than before, it can be concluded that the follow-up and the knowledge imparted here led to a reduction in reactance and the development of behavioral options that provide security. However, it is necessary to verify and confirm this result through further research.

The following overview in Table 3 shows in a comparison to which criteria the follow-up has brought about a change in the participants' ways of thinking and convictions. Furthermore, it should be shown, which needs that the follow-up was able to address and to what extent.

The latter criterion "Reactant reactions as a result of the fear appeal" confirms the research results of the impact evaluation by Prof. Dr. M. Hackenfort, ZHAW Zurich on the *Crash Course NRW,* according to which reactant behavior was also observed in individual cases.

The focus should be on the participants who developed reactance during the stage event and therefore belong to the risk group. The connection of the content of the stage event to the topics in the schools, then also to the topics of the follow-up, is very important in this context (Hackenfort, 2013, p.155–160).

Here, too, it must be assumed based on this information that reactive behavior in the form of rejection of the event and negation of the danger is hidden behind these statements.

Quality criteria

When evaluating research results, there is a scientific consensus that research processes must be transparent and comprehensible, and that the quality of the results must be comprehensible in terms of their significance. Quality characteristics of validity, reliability, and objectivity are often used as core criteria in this procedure (Döring and Bortz, 2016, p. 107).

The overview of Table 4 shows the extent to which the quality criteria were taken into account in this pre–post-survey:

With regard to explorative research, an identical transfer of this process in qualitative research hardly finds acceptance. There are two problems with this approach. On the one hand, the systematics as well as the definitions of quantitative quality criteria are not infrequently used blurrily in these transfer attempts; on the other hand, it makes less sense to import criteria for studies that follow a completely different paradigm of scientific theory into the qualitative paradigm (Döring and

TABLE 3 Comparison of criteria of settings preliminary research ($n = 77$) and post-test ($n = 57$).

Category	Before	Afterward	Result
Prior knowledge	14 participants did not know/rather not know that accidents can have these consequences 55 participants found it important to talk about traffic accidents	28 participants stated that they had received good information on the causes of accidents, accident risk behavior, and road safety behavior	Participants could be reached and knowledge could be imparted
Cause of accident	42 participants wanted the causes of the accident to be addressed in the follow-up	28 participants stated that they had received good information on the causes of accidents, accident risk behavior, and road safety behavior.	Participants could be reached and knowledge could be imparted
Prevention	52 participants wished that it was addressed how an accident can be prevented 67 participants wanted to prevent something like this from happening to them	28 participants stated that they had received good information on the causes of accidents, accident risk behavior, and road safety behavior.	Participants could be reached and knowledge could be imparted
Risk situations	51 participants wished that it was addressed which situations in road traffic are dangerous	10 participants did not recognize the danger in the maps shown for various dangerous situations	Some participants could not be reached spontaneously
Laws	46 participants wanted to find out more about the legal situation	28 participants stated that they had received good information on the causes of accidents, accident risk behavior, and road safety behavior.	Participants could be reached and knowledge could be imparted
Health	40 participants wanted to find out more about the influence on health and traffic risks	28 participants stated that they had received good information on the causes of accidents, accident risk behavior, and road safety behavior.	Participants could be reached and knowledge could be imparted
Alcohol, drugs, medication	44 participants wanted to know what exactly causes alcohol, drugs and medication	34 participants consider alcohol and drugs to be a dangerous risk factor, 11 participants consider drinking a little alcohol to be harmless	Most participants could be reached, and some participants could not. Here, reactance could be the cause of persevering in the mind.
Reactant reactions as a result of the fear appeal	1 participant was completely / 5 participants rather afraid to drive a car themselves 14 participants were annoyed 10 participants would have preferred to go outside 7 participants will not / 23 rather not recommend the event	Only 5 participants want to do something reckless now more than ever	No further interviews were conducted thereafter that would have clarified whether follow-up neutralized reactive thinking and strengthened self-efficacy. More research needs to be done here in the future

Bortz, 2016, p. 107). Here, it is more about representativeness in terms of content rather than purely statistical representativeness. More widely accepted than the adoption of quantitative quality criteria is a second approach, which aims to develop its own quality criteria from the logic of qualitative research and to specify the techniques for ensuring them. Against this background, further quality criteria have been developed in qualitative research, which are reviewed in Table 5 below according to Mayring (Godbersen, 2020, p. 11):

The impact of the Corona Protection Ordinance allowed only one event to be held, so that only four classes could be compared and the exercises could only be replicated to a limited extent. Whether the lessons learned, as well as the initial consolidations, remain manifest must be tested in follow-up events.

Answers to the research questions

Q1: Which didactic methods are suitable to extract and reinforce the safety messages of the stage event?

Q2: Which didactic methods are suitable to influence risk behavior in an empathy-expanding way?

The results of the post-survey (4.2.1) showed that the content-related needs of the participants were met during

TABLE 4 Overview of the quality criteria of the preliminary test and post-test.

Quality criterion	Pretest	Post-test	Explanation	Result
Objectivity (measurement is independent of the person)	Survey was conducted anonymously by a shared QR code. Instructions for the survey where read to the participants during the introduction	Survey was conducted anonymously by a shared QR code. Instructions for the survey where read to the participants during the introduction	No influence by the interviewer possible	Objectivity is given
Reliability (if the survey is repeated, the measurement result is the same)	Survey was conducted in four classes.	Survey was conducted in four classes.	The results are evenly distributed in all classes. The only significant response in the pre-set is the participant who is afraid to drive a car now.	Survey has a high reliability
Validity (what is to be output is measured)	The reaction to the Crash Course NRW stage event was to be examined in all classes.	The effectiveness of the follow-up to the Crash Course NRW stage event was to be examined in all classes	The questions relate specifically to the two events	Validity is given

the follow-up training. The following methods from cognitive behavioral therapy were used:

- Methods that critically examine self-reflective own behavior and attitudes, norms and values, and risk and supposed security (cognitive restructuring according to A. Beck).
- Methods that expose contradictions in thinking (disputation techniques according to A. Beck).
- Methods that contrast possible courses of action and thus offer decision-making options (problem-solving training according to A. Beck).
- Methods that explain safety concepts and provide sufficient information about risks.
- Methods that strengthen self-efficacy (Socratic dialog).

These methods were used together with the tools to make the participants change their thinking. The results related to the effectiveness and usefulness of the tools *"Risk Scale," "Intoxication Goggles,"* and *"Role Play"* in the *post-test* showed that the methods were successful in initiating a change in thinking. It was possible to launch a new and improved view of risk events in road traffic and to achieve more sensitivity. In addition, improved and new behaviors toward more safety behaviors could be implemented, including a *"Plan B"* to be able to get out of an unsafely driven vehicle *via* pretending to vomit.

Individual needs, such as the need for knowledge about the aftercare of traffic accident victims, as well as the individual emotional situation, such as fear of driving, should at best be taken into account and successfully included in the search process by responding accordingly.

Q3: How must a follow-up module be designed in terms of content in order to be able to attach important road safety messages in the long term?

According to the results of the preliminary research (4.1.1), attendants need answers to the following issues after being confronted with real accidents in an accident prevention campaign;

- Accident avoidance strategies.
- Consequences of alcohol and drug use.
- Influence of own health status on road safety.
- Legal knowledge and,
- Accident follow-up.

In the course of the post-survey related to the questions on alcohol, drugs, the learned new safety behavior and related to the own possibilities of change, but also related to the discussions on post-accident care and on physical impairments due to medication on driving ability, it could be determined that these are suitable to establish an adequate exchange on traffic prevention topics and to fill knowledge gaps. The use of the supportive exercises carried out initiates simulations that are close to real life. The exchange of experiences in the peer group during the individual exercises helps to convey the messages adequately. In the post-survey, the respective questions about the exercises reflected the recognizability to everyday life and the usability of the exercises for the transfer into the same.

To solidify these findings, further research should be conducted after the COVID-19 Protective Measures have ended and prevention programs and large audience have resumed in schools.

Q4: Was reactive behavior generated by the Crash Course NRW stage event and could it be minimized through follow-up?

The preliminary survey clearly showed that reactive behavior was generated. (Appendix Preliminary Test):

(SQ006) *"I was annoyed" (20%).*

(SQ007) "*I would have loved to walk out" (13%).*

(SQ008) "*I have no interest at all in a follow-up" (24%).*

(SQ008) *"I will not recommend the event to others" (40%).*

The need to leave the event and the statement not to recommend it to others may be interpreted as rejection and

TABLE 5 Quality criteria of observational research according to Mayring, $n = 86$.

Quality criteria	Brief description	Remarks
Procedural documentation	Procedural documentation means documenting every step of the analysis. Typically, qualitative content analyses according to Mayring begin with transcriptions. Finally, a results section is written.	Handwritten notes were made during the event, which were compiled into documentation and the production of tables on the PC in the immediate aftermath. These were supported by photographs taken on site.
Argumentative interpretation validation	Interpretations must be justified by argument: Criteria are: (a) adequate prior understanding of the interpretation b) interpretation must be coherent in itself c) alternative interpretations must be sought and verified d) negative interpretation can be an important argument for the validity justification	a) Due to the already existing research by M. Hackenfort on Crash Kurs NRW, it was possible to draw on existing findings and to put the results in the context of already acquired interpretations. b) This approach facilitated the embedding of the new findings into the overall context. The comparison of the existing results with the new results is conclusive and builds logically on each other. c) A comparison with the arguments of fear appeal research in health research (e.g. anti-smoking campaigns) can be made. The results are comparable and reveal the identical psychological dynamics d) The negative effect in fear appeal research, the so-called boomerang effect, which triggers reactance behavior, is a strong measurable factor for the impact of the campaign. This can be seen in negative interpretations
Rule-governed	Quality of interpretation is achieved through a step-by-step, sequential approach. Analysis steps are defined in advance and carried out systematically. These rules concern the material that is included in the analysis and how this is handled.	The content and sequence of the exercises were determined in advance, as they build on each other thematically. The same material was always used for the exercises. The presentation of the respective exercises was always done in the same style. The same materials were used in the same order in all four classes. The content of the discussions varied because the norms, values and attitudes of the students were different.
Proximity to the object	Proximity to the subject means that, at best, interview partners are interviewed in their usual environment. The reason for this is that people always behave somewhat differently in different environments and may also say different things.	During the follow-up training, the participants were in their class within the class group. This is generally a familiar environment. The class teacher, who was also a familiar person, was present throughout. There was a risk that socially desirable behavior would be exhibited in the presence of the class teacher. However, when weighing up the possibilities of coming into contact with pupils of this age for traffic accident prevention campaigns, this represents the best possible variant.
Communicative validation	The validity of the results, the interpretations is thereby checked, by presenting them to the researched and discussing them with them.	The results of the discussions on the exercises were publicly discussed directly in the plenum. Feedback on this could also be given directly below the participants. The results of the anonymous online survey could not be disclosed because they were only evaluated after the school event.
Triangulation	Triangulation can be performed by conducting another qualitative content analysis. Different data sources, different interpreters, different methods or theoretical approaches; results of the different perspectives are compared with each other and formed into a kaleidoscope-like picture composed.	As a result of the outbreak of the pandemic triggered by COVID-19 shortly after the implementation of this follow-up, there was a lockdown and a halt to all school activities. As a result, all *Crash Kurs NRW* events were canceled. No more classes could be taught and therefore no more research results could be collected. Only these four classes could be evaluated against each other.

defensiveness toward the event. These responses were not picked up in the post-survey because they could not be acted upon quickly enough.

However, the research at this school has now brought attention to this reactance and another iterative pass will revisit this research question.

The post-test showed reactive behavior even after the follow-up:

(SQ007) "*I'm going to try something reckless now" (9%).*

In comparison, however, this result is significantly lower than the evidence in the preliminary test. Therefore, it may be concluded that the follow-up training was able to minimize the

reactance behavior through the application of the educational and self-efficacy strengthening tools.

Limitations

Limitations of the road safety prevention concept

Following the findings already obtained from the research of Hackenfort et al. on the impact evaluation of the Crash Course NRW stage event, it is not surprising that isolated reactance behavior can be observed despite a well-founded follow-up concept. The confrontation with life-changing events such as accidental injuries or accidental death and also the regulating roles of state legislation are the subject of the lesson follow-up and *per se* suitable to clarify a restriction of personal freedom or also the restriction of personal inviolability. The extent to which there is a willingness to accept one in favor of the other in a weighing of interests depends in particular on the constellations of personal norms and values and cannot always be cognitively restructured within two or three teaching units. Here, a limit of the instructional follow-up must be defined, because the more deeply a normative principle is anchored in personal attitudes, the more time a cognitive reevaluation requires. Also, dynamics such as convenience, group status, or simply dysfunctional habits must be considered here, first detected, and then resolved and transformed. This is often not feasible through a one-time instructional follow-up.

Limits of the study

Specific driving behaviors in traffic settings, such as steering, braking, or accelerating behavior, cannot be recorded with this study. Also not covered are personal indicators such as responsiveness, cognitive, or physical parameters that could result in any driving impairment and thus a risk factor for road safety.

Comparison of results with other studies

Comparable studies that have looked at the effectiveness of promotional campaigns in the road safety sector have also concluded that the effectiveness of an intervention measure increases when it is linked to a traffic education program or sanction (Faus et al., 2021b, p. 21). These findings support the intention to reinforce the safety-related messages from the Crash Course NRW stage event through instructional follow-up and to make them concretely actionable for participants through role simulations that are true to everyday life.

A study from the Dominican Republic that looked at the factor of remembering safety-related messages from traffic prevention campaigns found the following variables to be authoritative: driving a motor vehicle, habitual driving, and possession of a driver's license were causally related to retention of information. Thus, these variables are obviously key elements that distinguish drivers from non-drivers (Faus et al., 2021b, p. 15). However, the instructional follow-up of the Crash Course NRW stage event is aimed not only at young drivers but also at co-drivers aged 16 and above. This therefore includes road users who are not yet drivers and those who are still in training to obtain a driving license. The campaign also intends to sensitize future driving license holders already, to make them aware of the dangers of road traffic and to have a positive influence on them as co-drivers. This was also taken into account in the present research under the aspect of the assumption of responsibility by the co-driver.

Research gap

In spite of all the attention paid to the appreciative and constructive resolution of inner resistance to a new way of acting and behaving in road traffic, it is important to focus on yet another aspect that has not yet been addressed in this research: the question of whether the presence of police officers in the follow-up training can have a dysfunctional effect. In principle, schools are supposed to carry out the classroom follow-up, but sometimes, schools make use of the support of the police in the form of a traffic safety seminar in order to convey in-depth contents of the Crash Course NRW stage event. Here, the question arises whether the renewed presence of police officers maintains reactance or even exacerbates it. Depending on such a research result, schools and the commissioning ministry could be given a clear recommendation for the implementation of the follow-up training.

Conclusion

Temporarily interrupted by the COVID-19 pandemic, research should continue with the resumption of *Crash Course NRW* events to produce a valid result.

The obtained results from the post-survey reflect that the applied methods of cognitive restructuring, guided discovery, and structured recognition of potential hazards in the exercises that ultimately led the group to gain knowledge are the right ones (post-survey Appendix).

Important remains basically the message from the fear appeal the trailblazing saving action option to hire. It is important to recognize that effective traffic accident prevention can only be successful when emotionalizing content is applied if stabilizing elements and concrete instructions for action are offered afterward.

The "Get off the gas!" campaign, as a comparable counterpart in traffic accident prevention, also has a very stable

body of evidence in this regard (Holte, 2012). In addition to a higher willingness to take risks as a result of sensation seeking, an exaggerated expectation of self-efficacy, i.e., confidence in one's own driving abilities ("I am a particularly good driver") plays a role (Holte, 2012).

A misjudgment in any direction of one's own ability will always have a negative effect on lived road safety.

We have to accept: Young drivers will always be difficult to convince. Despite all campaigns in favor of attention, this group remains the "problem child" in traffic accident statistics.

Ultimately, it remains to be considered how the contradiction between the search for stimuli and the exaggerated, erroneous confidence in one's own driving skills on the one hand, and the existing expectation of self-efficacy through emotionalizing campaigns on the other, can be resolved. Through the developed training, it can be possible to uncover exactly these contrary erroneous assumptions and shift them into a true reflection of reality, thereby increasing traffic safety behavior.

If making correct decisions relevant to traffic safety is the result, every event has achieved its goal.

Future research

In a subsequent research, we show how another iterative loop comparatively addresses the issue of fear appeals in an alternating police traffic accident prevention event. Here, we will explore in more depth whether certain criteria repeatedly lead to reactance, which is minimized by consistent intervention:

Effectiveness of intervention measures against the reactance effect in school safety prevention.

Referring to the research findings of Hackenfort et al. a third publication is discussed. It was suggested by Hackenfort et al. to generate further knowledge in an "accident scene analysis" and to transfer it to the knowledge gained in the Crash Course NRW stage event (Klimmt et al., 2015, p. 257). In this way, options for action in traffic safety-relevant behavior should be acquired and thus the boomerang effect minimized.

To achieve this, local accident hotspots can be analyzed and vulnerable danger spots such as school routes can be focused on.

This option can also be used as a follow-up to Crash Course NRW to gain a better understanding of risk situations and safety behavior.

Also building on this study, a further iterative loop of a subsequent publication will focus on such a form of gaining knowledge.

In addition, this form of teaching can target digital teaching in times of lockdown and take into account the current requirements of public health developments:

Traffic space analysis in the blended learning method–a new teaching style of traffic safety in times of COVID-19.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/Supplementary material.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

SB developed to the conception and design of the study, wrote the manuscript, conducted the follow-up training and the part taking observation, and developed and evaluated questionnaires for the preliminary research and the post-test. AB and SB led the design of the follow-up training. All authors approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.1046403/full#supplementary-material

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3.2.2 Wirksamkeit pädagogischer Interventionen zur Minimierung der Reaktanz bei der Verkehrsunfallprävention

Einleitung: Im Bereich der Verkehrssicherheit sind die Konzepte der klassischen Mechanik zentral, um physikalische Probleme zu verstehen und zu lösen. Diese beinhalten Geschwindigkeit, Beschleunigung, Bremsweg, Aufprallgeschwindigkeit, Verformung, kinetische Energie und deren Auswirkungen auf Fahrzeuginsassen. Die Anwendung statistischer Physik erklärt das kollektive Verhalten mehrerer Fahrzeuge als System mit vielen Teilchen. (Leventhal, H., Hirschmann, R., 1982). Diese Studie untersucht die Wirksamkeit der Einbeziehung eines beschädigten Autos und strukturierter Unterweisung in Verkehrssicherheitsinitiativen.

Methoden: Die Teilnehmer*innen beschäftigten sich mit einem beschädigten Auto und diskutierten die Verformung durch überhöhte Geschwindigkeit auf physikalischer Ebene. Sie nahmen ebenso wie die Teilnehmer*innen aus Studie 1 an Rollensimulationen teil, diskutierten riskante Verkehrsszenarien und entwickelten Plan-B-Lösungsstrategien. (von Beesten S., Bresges A., Lubert D., 2024).

Fazit: Die Kombination emotionaler Appelle mit lösungsorientierten, handlungsorientierten und selbstwertsteigernden Interventionen ist entscheidend, um den Bumerang-Effekt abzuschwächen und sicherheitsgerechtes Verhalten zu fördern. (von Beesten S., Bresges A., Lubert D., 2024).
Diese Erkenntnis unterstützt bisherige Forschung, dass Bildungseinrichtungen maßgeschneiderte Folgemaßnahmen für emotional aufgeladene Präventionskampagnen durchführen müssen (Dillard J.P., Shen L., 2005).

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Effectiveness of educational interventions in minimizing reactance in traffic accident prevention

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Introduction: Classical mechanics concepts are vital for understanding traffic safety, encompassing speed, acceleration, stopping distance, impact speed, deformation, kinetic energy, and their effects on vehicle occupants. Statistical physics principles are also employed to study multiple vehicles as a many-particle system. This study examines the effectiveness of using a damaged car and structured instruction in road safety initiatives.

Methods: Participants engaged with a damaged car and discussed deformation caused by excessive speed. They participated in role simulations, envisioning and solving risky traffic scenarios, while considering the potential boomerang effect resulting from excessive fear appeals within the campaign.

Results: Combining emotional appeals with solution-focused, action-oriented, and self-esteem-enhancing interventions is essential to mitigate the boomerang effect and encourage safety-compliant behavior. Educational institutions must implement tailored follow-ups to emotionally charged prevention campaigns. Using Design-Based Research, we developed effective methods for knowledge acquisition and transfer, drawing from cognitive behavioral therapy and established traffic safety programs.

Discussion: This publication explores non-standardized social training within focus groups, focusing on negative emotional states following an emotionalizing campaign similar to "*Crash Kurs NRW*," targeting upper-level courses in North Rhine-Westphalian schools. Methods from cognitive behavioral therapy and social learning initiated, observed, and documented changes in participants' norms, values, and attitudes, discussed herein. Additionally, we investigated whether the presence of police officers in prevention campaigns influences reactive behavior. Comparing pre- and post-surveys confirmed reactance after emotionalizing campaigns, and our structured post-survey effectively influenced stage-event-induced behavior. Surprisingly, police officers' presence did not significantly impact reactive behavior. Furthermore, our follow-up tool extends its applicability to similar emotionalizing prevention campaigns, broadening its potential reach. Our future research will delve into students' physics literacy during traffic space analysis of accident hotspots, advancing traffic safety initiatives.

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KEYWORDS

design based research, road safety, Crash Kurs NRW, safety behavior, road accident avoidance, reactance behavior

1 Introduction

The question of the greatest possible potential for learning, the imparting of knowledge, and a concomitant change in behavior is an omnipresent phenomenon in our educational society (Petermann and Petermann, 2018, p. 12). The aim is to achieve a high level of fit between the parental home, educational and upbringing institutions, and leisure peer group. In this context, the level of school-based traffic and mobility education plays a prominent role because of the high accessibility of the target group as a result of compulsory schooling (Klimmt et al., 2015, p. 16). Therefore, we use an interdisciplinary approach in our constant search of implementable practices in teaching, which can impart knowledge more efficiently and sustainably and use human comprehension to its full extent. In particular, the implementation of behavioral change, as an observable criterion of learning success, is of special importance in educational and preventive work. This also applies to the area of traffic accident prevention, which, according to the decree, includes traffic safety work in North Rhine-Westphalia (NRW) as a necessary component in addition to repressive and public relations work (Road safety work of the police,[1] March 17, 2023). In Germany, traffic education and traffic information are located at different levels of society and are characterized by interdisciplinary cooperation and diversity.

The Ministry of Education and the Ministry of the Interior have set a joint course for safety in this area by making traffic accident education and prevention the focus of curricular provisions, for which teachers can enlist the support of police departments or traffic guards.

According to the "Adjusted Official Collection of School Regulations" (BASS) in North Rhine-Westphalia, traffic education and mobility education in schools as part of their teaching and educational mission is appropriate for all grades and types of school (BASS, Road safety education and mobility education at school,[2] March 17, 2023). In this context, traffic education and mobility education, if not anchored in the curricula, is understood as a cross-sectional task of all subject areas, and may be implemented in different forms, including projects.

This provision provides a variety of options for teaching traffic safety aspects and safety-conscious behavior in addition to curricular instruction.

Since mobility experiences are made in all areas of life and at all age levels, it should be adopted at all age levels in an age-appropriate and adequate manner while ensuring that beneficial messages are strongly reinforced.

The curriculum for physics instruction at the upper secondary level declares the competency expectations and content priorities for students until the end of the introductory phase (School development and curricula,[3] March 17, 2023).

Road safety training programs are also a common means of raising awareness of risky attitudes and behaviors. While road safety courses for children are regularly evaluated, there is generally a lack of comparable evaluation for young people and adults. A recent systematic review aimed to identify studies that evaluate the effectiveness of road safety training programs in this age group. This review followed the PRISMA methodology to identify relevant articles using predefined research criteria. A total of 1,336 indexed articles were searched, and finally 22 articles directly addressing the topic were selected (Faus et al., 2023).

The search strategies spanned various databases such as WOS, Scopus, NCBI, Google Scholar and APA. The selected articles suggest that the effects of traffic safety training programs in adults are generally classified as mild to moderate. However, the effectiveness of these programs is significantly enhanced when they aim to improve risk perception and decision making rather than focusing solely on driving skills. In any case, the review highlights the need for further evaluation of such courses to identify which tools are actually effective and which should be replaced by new behavior change methods in the design of future driver education programs.

This research study presents an innovative pilot campaign for a little-researched target group of young adults, in which an accident car was used as a visual element to illustrate the reality and potential consequences of risky driving behavior. This campaign is part of the *Crash Kurs NRW* campaign, which has been continuously implemented in schools for the defined target group since 2010. The evaluation of the effectiveness of the original intervention by Hackenfort et al. (2015) showed a resulting reactance with insufficient follow-up, as described in Section 2.2.

An accident car can also serve as an illustrative example in science lessons to explain physical principles in the context of road accidents, such as kinematic variables in a collision. By analyzing the traces of the accident and damage, pupils can gain an insight into the forces and energies at work in a traffic accident. This enables a

1 www.recht.de

2 www.bass.schul-welt.de

3 www.schulentwicklung.de

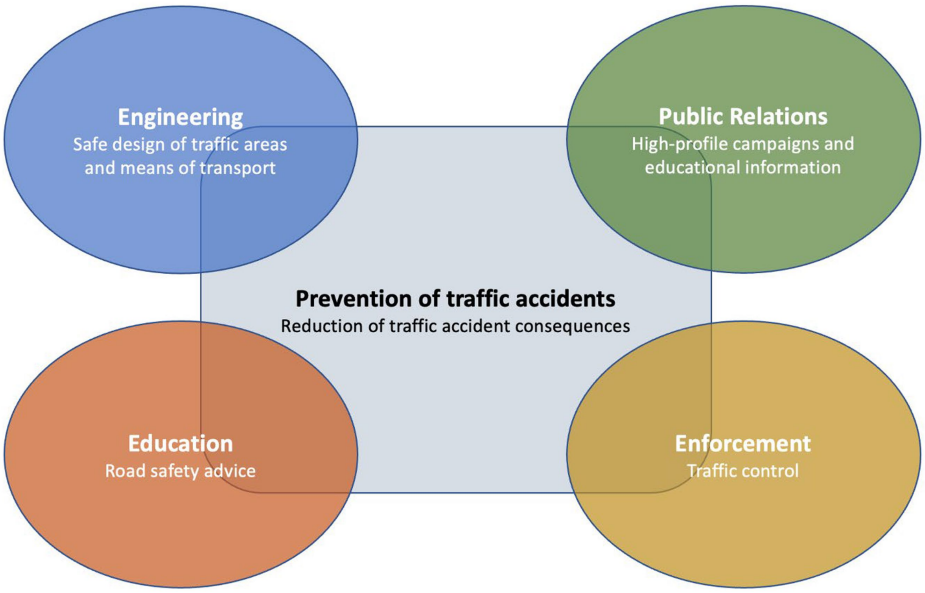

FIGURE 1
Overview of the impact levels of traffic accident prevention (source: own representation).

practical application of scientific concepts in the context of road safety.

Road traffic processes can therefore be used to achieve a higher level of education by analyzing, evaluating and interpreting the results, both in terms of acquiring technical skills and in the context of gaining knowledge.

When implementing a scientific link with a preventive traffic accident campaign, not only are the contents of core curricula fulfilled, but the behavior-oriented goals of traffic accident prevention campaigns are also achieved.

This paper will present such a concept.

2 Theory

2.1 General framework

Mobility, and by association participation in the social environment, is an increasingly complex and demanding process, which in many areas requires a deeper awareness of the processes involved and a sensitization to one's own possibilities of exerting a positive influence.

Road safety consulting is intended to provide early and long-term work based on the principle of lifelong learning. These measures are coordinated with each other in the age groups and their content is tailored to the target group. Road users are to discover cooperative behavior as positive and be strengthened in their personal and joint responsibility. Road safety advice is intended to inform road users and their multipliers, e.g., parents, educators, associations and other bodies for their road safety work, about developments and findings relevant to road safety as well as roadworthy behavior (Polizeidienstvorschrift PDV 100, Polizeifachhandbuch NRW, 2021).

An improvement in traffic safety can only be achieved if

- the traffic awareness of the individual road user
- their inner attitude to the whole traffic process
- their attitude towards other road users and
- their attitude to the traffic rules is undergoes positive change.

Traffic accident prevention takes place at the following levels (see Figure 1).

Teaching and education in particular are intended to address and raise awareness among the target group of young drivers, who occupy a special position due to their developmental specificity. According to a study by the Allianz Center for Technology, globally, more young people between the ages of 15 and 29 die in traffic accidents than from illness, drugs, suicide, violence or war events. Overall, that amounts to about 400,000 per year (March 17, 2023).[4] Three main constructs may be cited as reasons:

- teen drivers overestimate themselves and their abilities
- young people consider themselves invulnerable (Linneweber, 2003, p. 291)

4 https://www.allianz.com/de/presse/news/engagement/gesellschaft/141029-allianz-zur-sicherheit-im-strassenverkehr.html

- the phenomenon of conscious risk-connotative behavior (Raithel, 2013, p. 31)

While the general risk of being young is a normative behavior inherent in the life phase, the beginner's risk is independent of age and relates to the basic skills of driving technique. These include, for example, mastery of vehicle technology or the ability to adequately assess constantly changing traffic situations (Bastian, 2010, p. 87).

Deliberately risk-connotative behavior includes actions such as subway surfing, risky dares, or influencing traffic in a dangerous manner. In this instance, the risk may relate either to one's own integrity (illegal street racing) or to that of others, e.g., opening sewers or throwing stones or manhole covers at moving vehicles (Raithel, 2013, p. 31).

In all activities, a high degree of criminal energy may be assumed as well as the conscious acceptance that damages may occur [BGH judgment in the stone-throwing case of January 14, 2010 (4 StR 450/09)].

Against the background of these findings, it is necessary to detect and reach particularly those young road users who are prone to be involved in traffic accidents due to their deliberately risky behavior by means of multiple measures of intervention in the sector of traffic accident prevention.

For road safety work, this emphasizes the necessity to approach young drivers directly: in schools and educational institutions, in the context of work and family, in the peer group.

The success of interventions depends on the following parameters:

- age- and development-appropriate communication of traffic-related messages
- visiting the target group in their living environment (settings)
- targeted thematic addressing, as it is more effective compared to generalized campaigns
- continuity of interventions depending on the developmental transition phases (from child to adolescent, from adolescent to adult)

Particularly in the transitional phases of development, people are highly receptive to information that explains the necessity of reflecting one's own behavior and that yields an increase in coping skills (Schneider, 2017, p. 31).

These aspects must be considered and implemented in the teaching of traffic accident prevention in order to generate a reliable indicator for the highest possible success.

2.2 Reactance behavior

A traffic accident prevention concept called *Crash Kurs NRW* was developed and launched by the *NRW* police with precisely this objective in mind.

The state campaign *Crash Kurs NRW* is a preventative initiative in North Rhine-Westphalia that aims to raise awareness of road safety. Through the targeted use of experience-oriented methods, such as the staging of accident situations, young people in particular are to be made aware of the consequences of risky driving behavior. The campaign integrates various stakeholders, including schools, police stations and traffic wardens, in order to achieve a broad and sustainable impact in the area of road accident prevention.

Showing accident images in the context of reactance has a double-edged effect. On the one hand, drastic images can trigger an emotional response and raise awareness of the dangers of road traffic. On the other hand, there is a risk that people will react to such images with defense mechanisms, especially if they feel patronized or restricted in their freedom. Therefore, a balanced approach is needed when using accident images that promotes awareness without provoking reactance.

A recent study by Dr. Elizabeth Box, which analyzed "shock and tell" approaches to road safety education, suggested that such tactics, which rely on evoking emotional responses through dramatic images, have limited effectiveness and can provoke defensive or even hostile reactions, particularly among young men. The research emphasized the need for an interactive approach in which facts about road safety are shared and young participants are encouraged to draw their own conclusions about safe driving behavior. These findings indicated that a traditional 'shock and tell' methodology may not be sufficient to achieve long-term impact (Box, 2023).

In a previous study that applied Kim Witte's Extended Parallel Processing Model (EPPM) to analyze road safety commercials in Russia, it was found that threat messages outweighed efficacy messages in the commercials. This suggested that an overemphasis on danger without sufficient emphasis on coping messages can lead to increased reactance (Ngondo and Klyueva, 2019). The EPPM, as a theoretical framework in communication and health psychology, distinguishes appropriate fear from defensive reactions to threats and has been used to evaluate the effectiveness of road safety messages.

Combining these findings, it is emphasized that balanced road safety education should communicate both dangers and concrete coping strategies to minimize the development of reactance. This underscores the importance of evidence-based interventions and an interactive approach based on research and behavioral psychology to achieve sustainable impact in road safety education.

The impact of *Crash Kurs NRW* was investigated by the Zurich University of Applied Sciences (by Hackenfort et al., 2015). The following criteria were collected for the impact study:

- subjective judgment of dangerousness
- self-competence assessment
- attitude to road safety
- safety-relevant knowledge and
- acceptance of the intervention (Gansewig and Walsh, 2020, p. 67)

The results demonstrated that a high level of acceptance of the event was still present months later. Hackenfort et al. again studied the *Crash Kurs NRW* campaign as part of the evaluation of a prevention measure for young novice drivers in Lower Saxony. The results showed that participation in the campaign had a positive effect on the driving behavior of participants and increased their willingness to avoid risky driving maneuvers (Hackenfort et al., 2018).

Additionally, it has been established that campaigns with so-called fear appeals, while initially generating widespread

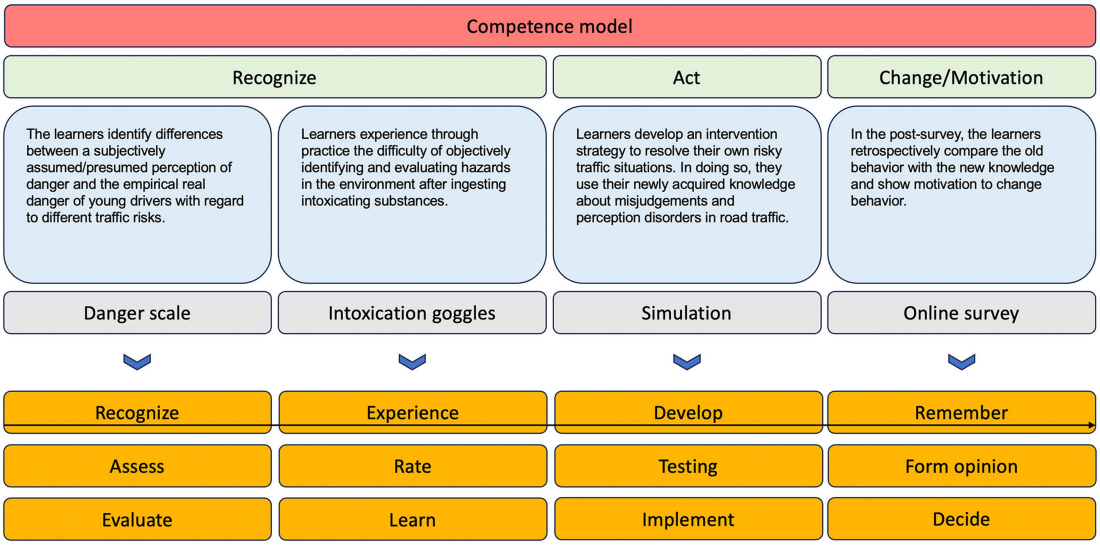

FIGURE 2
Competency model for content, recording and balancing individual learning outcomes via the applied follow-up tools (source: own representation).

attention, also more easily lead to reactance and rejection of the desired change in behavior by the at-risk group. Reactance behavior refers to the tendency of individuals to react negatively to actions or restrictions that are perceived as limiting their freedom or autonomy. To minimize reactance behavior, it is important that traffic prevention measures be transparent, fair, and meaningful. Thus, police should communicate the measures well and explain why they are necessary. Evidence from research studies suggests that communication campaigns, related to traffic safety messages, may be rendered significantly more effective when accompanied by traffic education measures (Faus et al., 2021).

There are some studies that focus on the role of police officers in prevention campaigns and the associated reactance behavior of the public. Different studies show that the role of police officers in prevention campaigns is complex and depends on many factors. It is important that officers display a positive attitude during the campaign and that police presence is carefully balanced to minimize public reactance behavior and have a positive impact on behavior (Jeong and Lee, 2018, https://doi.org/10.1016/j.aap.2018.06.010).

For this reason, an instructional follow-up concept has already been developed in the context of the NRW state prevention campaign *Crash Kurs NRW*. The research results and derived requirements of Hackenfort et al. were taken up and developed in a research desideratum. This has subsequently been published at https://doi.org/10.3389/fpsyg.2022.1046403 (von Beesten and Bresges, 2022).

The core methods of the follow-up concept are methods from cognitive behavioral therapy and social training in focus groups, which are designed to teach skills and launch behavioral changes in sequential, multi-step procedures. The first steps are:

- dysfunctional assumptions are detected and re-evaluated (theory-based recognition)
- through self-awareness, existing misconceptions about risky traffic behavior are exposed as such (practical experience, evaluation, assessment)
- development of functional action strategies from the previously acquired knowledge through active practice in a role simulation and rehearse them for an emergency situation (practical transfer to everyday life, implement)
- the achievement of the goal should then be made measurable via evaluation

In this instance, the perception and recognition of risks and their evaluation are of central importance. The ability to recognize and avoid dangers from the environment is useful for all living beings to improve their chances of survival. The ability to preserve experiences with the environment and to learn from them increases these chances. Humans still have the chance to change their environment and can act actively and purposefully. Thus, they are able to not only create but also reduce risks (Jungermann and Slovic, 1993, p. 167).

Risk perception is divided into two main factors: perceived threat and perceived control. Perceived threat refers to the person's assessment of the severity of the potential harm or loss associated with a particular risk. Perceived control, on the other hand, refers to the person's feeling that he or she can control or influence the risk. Depending on the perceived controllability, the decision-making process takes place, which in turn dictates behavior (Raupp, 2012, p. 27).

The following diagram illustrates the processes of recognizing, assessing and evaluating, of learning, transferring into action and thus into the behavior shown, as well as of its evaluation as empirical evidence of any sustainable internalization. In addition, the methods used will be assigned to the respective sections (see Figure 2).

Q1: Does the modified concept of exhibiting a damaged car generate less reactance than Crash Kurs NRW?

Q2: Does the presence of the police lead to a change in reactance?

Q3: Can the instructional follow-up concept be successful in terms of a targeted change in behavior?

Q4: Is exhibiting a damaged car suitable for teaching physics topics?

At the vertical competence level, the various processes of follow-up aim at the following skills:

- *recognition* in the broader sense (related to hazards in general)
- *action* and
- *change (motivation)*.

In the horizontal competence level, the processes of follow-up aim at

- *recognition* in the narrower sense (related to dangers in concrete situations)
- *experience* (sensorimotor experience)
- *developing*
- *recall*

In the overall cognitive performance, human behavior should be positively influenced by the interaction of the prevention campaign and follow-up concept in favor of own health and traffic safety and public health and traffic safety.

2.3 Use of an exhibit

In 2022, a police department of the NRW police developed another project, which is intended to have an emotionalizing effect comparable to the *Crash Kurs NRW* stage campaign. By exhibiting a car that was damaged in an accident, participants are given the opportunity to come into real contact with a traffic accident. Since the participants are able to touch or rather "grasp" the damaged car, a real object is used to create a deeper understanding of the physical impact forces and to emphasize how powerless people are in the "traffic accident" process. Looking at a damaged car may have different effects on the observer, which may be beneficial in the context of road safety. Some possible effects are listed below:

- *Road safety awareness:* Looking at a damaged car may remind people how dangerous it can be to be to be driving or riding in a vehicle. Including information about road safety and accident prevention in the display may increase people's awareness of the risks on the road and help them drive more carefully and responsibly.
- *Raising awareness of the consequences of accidents:* Looking at a damaged car may also help people understand the impact of traffic accidents on those involved and their families. Thus, it may remind them of the importance of being careful on the road and obeying traffic rules.
- *Interest in vehicle technology:* A damaged car may furthermore arouse technical interest and encourage people to learn more about the safety features and technologies of modern vehicles. This can help get them interested in new technologies and developments in the automotive industry. This may subsequently lead them to be more likely to choose to purchase a vehicle with more supportive safety features.
- *Emotional reactions:* Looking at a damaged car might even evoke strong emotional reactions, especially if the occupants have been injured or killed. In some cases, this can also have negative effects (reactance), especially if visitors have had traumatic experiences with accidents.

Overall, the study indicates that accident exhibitions can be a useful tool for improving road safety if they are professionally designed and used in a targeted manner. In addition, it is shown that accident exhibitions can also play an important role in the cooperation between traffic authorities and other stakeholders, such as schools or road safety organizations. As a result, exhibitions about accidents may be designed to influence certain target groups more effectively (Tews and Krajewski, 2011).

The last two minutes before the crash are simulated with fictitious conversations of the vehicle occupants by playing audio files from the interior of the vehicle. Thus, participants are able to mentally put themselves in the same situation. Nevertheless, they are standing unharmed next to the exhibit and are still able to decide on looking after and maintaining their health. This crucial difference ought to be emphasized.

In addition, this study will investigate whether an emotionalizing concept comparable to *Crash Kurs NRW* elicits less reactance.

2.4 Theory-practice transfer of physics related topics on the basis of a damaged car

Theory-practice transfer in physics education refers to the ability of students to apply the theoretical concepts they have learned in class to practical applications and situations. This is an important part of the learning process as it allows students to deepen their understanding of the concepts and improve their skills in applying them (Habig et al., 2018, pp. 101–114).

There are several ways to promote theory-to-practice transfer in physics classes. One way is to have students perform hands-on experiments that illustrate the concepts covered in class.

Another way is to involve students in solving real-world physics problems. This can be accomplished through projects or activities that require students to apply their theoretical knowledge to solve

real-world problems. This can help students apply concepts in a real-world context and improve their ability to transfer theoretical concepts to practical applications (Demuth, 2012).

An important aspect of road safety research is crash testing, during which vehicles collide under controlled conditions to study the effects of crashes on occupants and vehicles. These tests serve to understand the effects of collisions on the bodies and protection of occupants, as well as evaluate the structural integrity of vehicles.

Furthermore, the results of crash tests can be used to derive physical rules and laws. For example, the results of vehicle-barrier collision tests may advance our understanding of the laws of motion and the law of conservation of momentum. Analyzing the kinetic energy and forces acting on an occupant or vehicle in a collision enables us to recognize how energy is transferred in such a situation and how we can improve occupant protection.

However, it is important to note that crash tests are only part of the broader spectrum of methods that can be used to derive physical rules and laws. Similarly, other methods, such as observations, measurements, simulations, and theoretical considerations, may be used to improve our knowledge of physics and enhance safety on the roads (Automotive test facility,[5] April 02, 2023).

In the present research work, the following research questions are pursued in accordance with the modified conceptualization of the Original *Crash Kurs NRW:*

3 Methodology

3.1 General framework

The sample group was taken from a vocational college.

A detailed overview of the composition of the research group and the comparison group in terms of age, gender distribution and educational qualification can be found in Supplementary Tables S1, S2.

The participants were grouped as follows:

All participants were pursuing the goal of practical training in combination with a higher education qualification. In this particular case, it was an apprenticeship in the field of automotive mechanics. The vocational college is located in a large industrial city in a rural environment. Car accidents are a constant issue, as most young people have access to cars and use them for travel and meetings in the weekends.

At this vocational college, the state-wide traffic accident prevention campaign *Crash Kurs NRW* has been carried out regularly by the local police for several years. Thanks to the close cooperation between the school's educational staff, the school management and the police's road safety advisory service, it was possible to initiate the implementation of the modified educational concept with an accident car in an initial pilot event with a zero group there. The close thematic connection between the college's subject area and road accident prevention means that the school has a constant need for prevention work.

The class was selected by the school management and the local police for a morning event at the school depending on the schedule. It had to be possible to access the nearby sports field without an audience and with privacy so that the trailer with the car involved in the accident could be set up there for the participants.

In answering the research questions, the differentiation from the original *Crash Kurs NRW* as well as a connection to science lessons should be clarified.

The student group was randomly split into two halves. The test group interacted with the police instructor, while the control group did not interact with the police instructor. This separation allowed the difference in reactance behavior between the group without police and the group with police to be empirically studied.

3.2 Exploration of knowledge acquisition with the help of the exhibit

3.2.1 The control group

The first half of the group was scheduled early in the morning. At that time, the police traffic safety advisory was not yet on site. Careful attention was paid in advance as part of the preparations to ensure that there were no clues to the exhibit or in the educational facility that would indicate that the police were associated with the campaign.

The group was introduced to the exhibit

- without explanatory preparation
- without the possibility to ask questions during viewing
- without recognizable/visible associated specialist personnel

It was only after listening to the audio files that the research creator raised questions about the preventability of such traffic accidents.

Then, Group 1 was led to the class room and the online survey questionnaire (pretest) was administered.

Afterwards, Group 1 was informed that they had participated in a police traffic accident prevention campaign.

3.2.2 The comparison group

The second half of the group was received and welcomed by the police in front of the school. They were reminded of the Crash Kurs NRW stage event they had attended together and interactively asked about the road safety messages from the event. The group was introduced to the topic. Thereafter, the police prepared the group for the accident car they were about to inspect. Some participants seemed to have already recognized the accident and also the occupants and their fate. Consequently, the first clarifying questions could be answered.

Afterwards, the group was introduced to the exhibit

- after adequate preparation
- with the constant accompaniment of the police as specialized personnel

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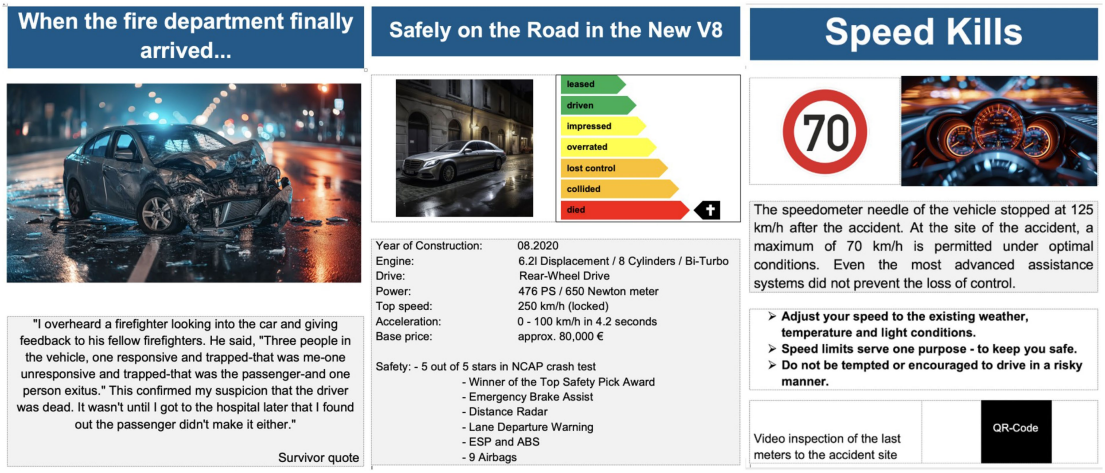

FIGURE 3
Exemplary excerpts of the steel images (source: created by the authors with Midjourney AI).

- with the constant possibility to inquire about the circumstances of the accident, causes of the accident, vehicle technology and accident prevention
- with static information displays providing information

Three exemplary illustrations of the information displays are shown in Figure 3.

The stele images show both targeted factual information, of physical and technical origin, aimed at avoiding traffic accidents as well as emotionalizing content that is intended to lead to a change in behavior at the relationship level. The additional possibility of addressing an auditory channel (audio files via QR codes) combined with the visual aspect ensures that the target group is more receptive to the information provided to them.

After playing the audio files, the question of the avoidability of such traffic accidents was raised again.

Following this, this group also conducted the online survey pretest in class.

The evaluation of the observations at the exhibit was carried out with the program MAXQDA®. The online survey of the pretest was conducted with the program LimeSurvey®.

The pretest was evaluated using the SPSS® program.

3.3 Exploring the acquisition of knowledge through classroom follow-up

The follow-up to the lessons was carried out in the entire class, again with the support of the police traffic safety advisors. This approach had the benefit of allowing for police-specific questions to be answered by the police themselves.

Since Group 1 did not have the opportunity to ask any questions about the accident at the exhibit the way Group 2 could, they were given the opportunity to do so.

After that, the instructional follow-up started with the following tools. The following Sections 3.3.1 to 3.3.3 have already been published as research desiderata in: Frontiers, https://doi.org/10.3389/fpsyg.2022.1046403 (von Beesten and Bresges, 2022).

3.3.1 The "*danger scale*"

By developing a danger scale along a marked axis between the extremes of "dangerous" and "not dangerous," the participants took responsibility for their own subjective perception of danger and their assessment of the dangerousness of various traffic situations. These individual assessments were then reviewed both within the class and in a moderated discussion, with a reassessment being carried out if necessary.

Repeatedly picking up and rearranging maps with depicted dangerous situations was a regular step. The accompanying moderation focused on weighing up the advantages and disadvantages of the hazard assessment of traffic situations and on presenting the current legal situation regarding these maps.

Guided discovery as a method from cognitive behavioral therapy was used to facilitate cognitive restructuring. The individual point of view and the perspective adopted were reconsidered as part of a Socratic dialog. By exposing and moderating contradictions, it was made clear that misconduct in road traffic is not beneficial and only appears logical on the surface. By creating confusion, distorted beliefs could be re-evaluated and dysfunctional distortions were restructured into realistic assessments (Revenstorf and Peter, 2015, p. 256).

The observation from the meta-level led to the realization that the previous way of thinking is only one of many possibilities and that alternative perspectives are just as realistic (Beck, 2013, p. 223 ff.).

The use of various disputation techniques of cognitive behavioral therapy, such as the logical, empirical and hedonistic style of disputation, made it possible to ask critical questions about thinking and behavior. These techniques encouraged deeper reflection on the motivations behind certain thought patterns, for example in relation to speed and road safety (Margraf and Schneider, 2018, p. 647).

Overall, these exercises initiated and anchored a process of cognitive restructuring. Joint discovery in the peer group played a

decisive role in this process (von Beesten and Bresges, 2022) (see Figure 4).

3.3.2 The *"intoxication goggles memory"*

Authorities and institutions dedicated to traffic accident prevention and education, such as the police, German Road Safety Association, ADAC and educational institutions, integrate intoxication goggles into campaign days and driver safety training courses to warn against the risks of alcohol consumption. These goggles have the ability to simulate different blood alcohol levels, creating visual impairments such as limited all-round vision, double vision, misjudgement of proximity and distance, confusion, tunnel vision, delayed reaction times and a feeling of insecurity. However, it should be noted that certain speech effects, such as "babbling," cannot be authentically reproduced (source: manufacturer Alcovista®,[6] November 23, 2023).

The simulation is limited to the visualization of selected intoxication effects, which are presented in a gradual representation of the blood alcohol concentration (BAC). The effects observed during the exercise were discussed with the group and served to examine dysfunctional assumptions with the help of the above-mentioned disputation style and Socratic dialog. As part of the exploration, an exchange of experiences on the effects of alcohol took place, whereby the legal basis and the associated consequences were also explained (von Beesten and Bresges, 2022) (see Figure 5).

3.3.3 The role play *"The last two minutes"*

The participants simulate a driving situation in which they can actively influence and test what happens through their own actions.

The typical causes of serious injuries in road traffic had been taught to the participants in the previous exercises and were therefore familiar with them.

However, knowing something does not necessarily mean being able to protect yourself against it. Initiating a specific action requires more than just the desire to do it and knowing how to do it, according to the "Rubicon model" by Weinert et al. (1987, p. 3 ff.). It is also essential to be able to access behavior that has already been actively performed, which can then also be recalled during stress.

According to Margaret Wilson's theory of "embodied cognition," it may also be possible to recall a behavior that is already known, an action sequence that has already been thought through, during stress. According to this theory, the body, mind and environment influence each other in the way we think, feel and act. Our thoughts trigger embodied reactions and vice versa (Wilson, 2002, p. 625). This means that every perception, both positive and negative, is stored as a body memory with the corresponding physical attitude at the time experienced. In this role-playing game, the assumption would be that the experience at the time of the driving simulation, including the associated posture and behavior, could be fully remembered and reproduced as an automatism in a later re-experience (Wilson, 2002, p. 634).

In this role play, the pupils are therefore asked to put themselves in the situation of a vehicle two minutes before a fatal crash. The social situation in the vehicle is presented to all pupils, e.g., by reading out the following text or by presenting a corresponding role diagram:

Through a conversation with the parents of one of the people involved in the accident, we know that the couple in the front seats were arguing when they left their parents' house. Jan and Marc are close friends, and Marc would never publicly criticize Jan, even if he made a driving mistake. Steffi is in a particularly socially awkward position: she has only been dating Marc for two weeks and this is the first time the group has taken her out in the evening. If she speaks out critically, she risks making a bad impression.

Exercise assumption: All the occupants of the car were killed in a night-time collision with an avenue tree at the weekend (source: University of Cologne, Crash Kurs NRW, November 23, 2023). Role-playing automates thoughts and behavioral sequences and reactions to them. By trying out new behaviors, assumptions and basic assumptions are changed, which in turn leads to new skills. Participants identify their own borderline situations and weak points and can develop solution scenarios (Beck, 2013, p. 257).

The role play initially offers a change of perspective from the outside role to the influential driver and passenger role, and gives participants the opportunity to actively lead a car journey to disaster.

Consciously bringing about a disaster with a subsequent analysis of the risk factors should, conversely, reveal protective factors that could have helped to prevent it (Beck, 2013, pp. 226–235).

Example: Loud music distracted the driver. Derived protective behaviors: Turn down music in the vehicle or turn it off completely.

We use participant observation to explore whether this type of educational role play is suifor recognizing risky actions in drivers. Furthermore, we test whether the passengers can recall and apply practiced actions to defend against risky behavior under simulated realistic conditions.

Intended goal: Educational role-playing should enable the recognition of dysfunctional actions and lead to more safety- and risk-conscious behavior by practicing modified functional actions (von Beesten and Bresges, 2022) (see Figure 6).

Following the in-class follow-up, the class completed the online posttest.

The analyses of the interviews, the observations and the discussions during the three tools were carried out with the program MAXQDA®.

The online survey of the posttest was conducted with the program LimeSurvey®. The posttest was analyzed using the SPSS® program.

3.4 Research of the reactance behavior

The pretest and posttest survey sets included reactance scales designed to measure the extent of reactance or resistance to a change or behavior. The two sets of pretests were divided into "with" and "without" police so that any differences could be measured. Reactance plays an important role in human behavior and decision-making processes. Understanding when and to what extent reactance occurs contributes significantly to counteracting it with appropriate measures and to improving the traffic accident prevention campaign to make it more effective. This can reduce the likelihood of rejection in the target group and increase the aspect of safety behavior.

6 https://alcovista.com/en/

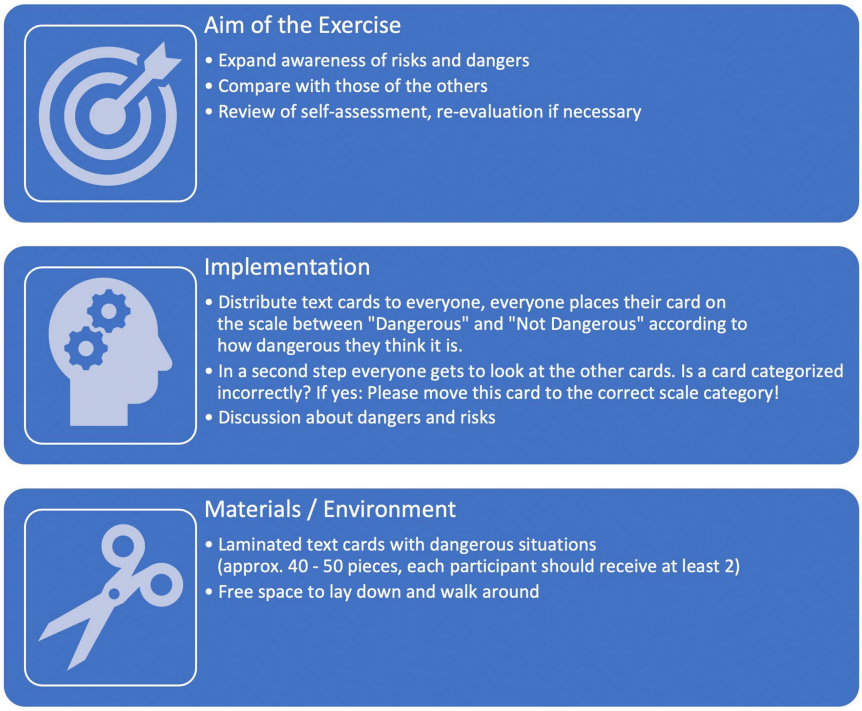

FIGURE 4
Overview of the "Risk scale" exercise.

FIGURE 5
Overview of the "intoxication goggles memory" exercise.

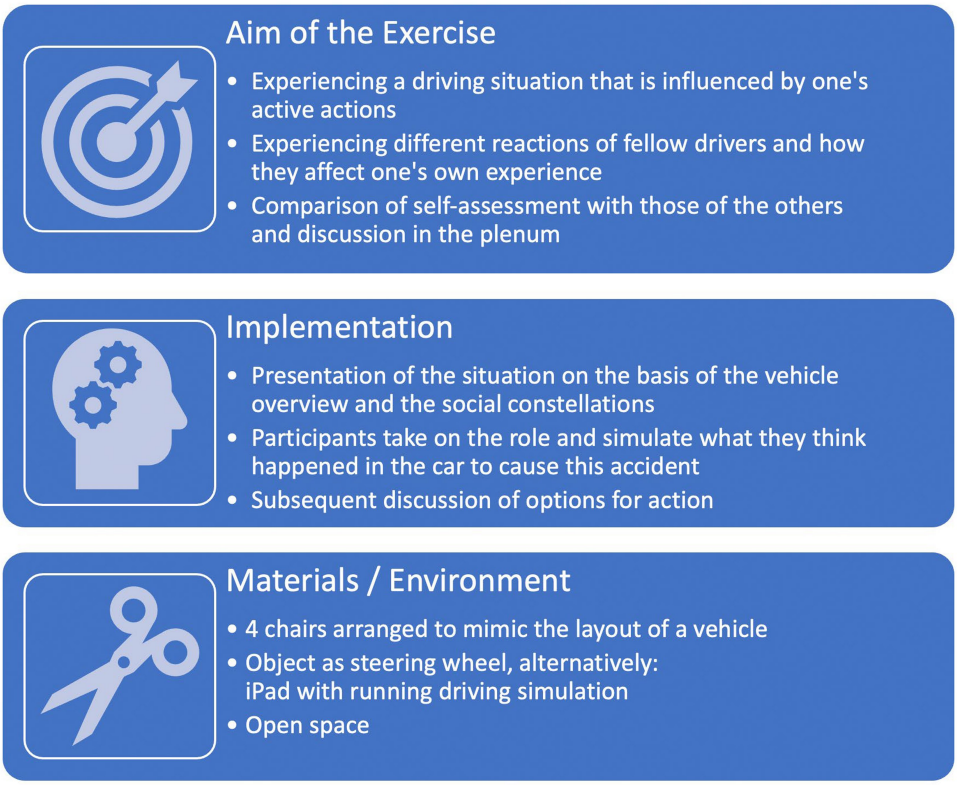

FIGURE 6
Overview of the exercise "The last two minutes".

In order to measure reactance, the present research work was based on excerpts of the questionnaire for the assessment of traffic-relevant personality traits (TVP) (Spicher and Hänsgen, 2003).

3.5 Theory-practice transfer of physical laws

The participants of the present research group were members of a technical vocational college. Hence, they already had a basic understanding of physics and technology and how they make sense of things. This could be confirmed by the statements made.

Accordingly, the probability that physical laws may be explained more effectively by practical observation and participation in an exhibition on the damaged car is very high. This is because practical experience and observation often make a stronger impression on our brain than merely theoretical explanations (Rösler, 2016, pp. 12–16).

By looking at and examining the car involved in the accident, it is possible to see, for example, how the forces affected the vehicle, how, where and with what force the impact occurred and what the consequences were. Due to the lack of a physics teacher, such an evaluation could not be done in this research round. There will be another research round that will address this question in particular.

4 Results

4.1 Results of the quantitative methods

4.1.1 Results of the reactance test related to the police presence

For this purpose, the reactance scores of both groups were first determined using the items from the pretest by assigning different points for the responses. The items chosen to measure reactance were as follows:

Part C/Item 8: I like to react to prohibitions with a "Now more than ever."

Part C/Item 9: I'm not interested in all these topics, because I do what I want anyway.

Part D/Item 1: I want to prevent the same thing from happening to me.

Part D/Item 4: I think it is important to talk about traffic accidents.

Part D/Item 5: I was annoyed.

Part D/Item 6: I would have preferred to leave the event.

Part D/Item 7: The event was a waste of time.

Part D/Item 8: An accident like this will not happen to me anyway.

Table 1 shows the points assigned to determine the reactance values:

TABLE 1 Overview of the scoring of reactance points according to answers in the pretest.

Reactance Points	0	1	2
Part C			
Item 8	do not agree at all / rather disagree	rather agree	fully agree
Item 9	do not agree at all / rather disagree	rather agree	fully agree
Part D			
Item 1	fully applies / tends to apply	rather does not apply	does not apply at all
Item 4	fully applies / tends to apply	rather does not apply	does not apply at all
Item 5	does not apply at all / rather does not apply	rather applies	fully applies
Item 6	does not apply at all / rather does not apply	rather applies	fully applies
Item 7	does not apply at all / rather does not apply	rather applies	fully applies
Item 8	does not apply at all / rather does not apply	rather applies	fully applies

Source: own representation.

The sum of all reactance values of the different items then results in the individual reactance value of the respective participant.

This overview provides the frequency distribution of both variables and thus gives information on how often a certain reactance value was reached in the respective group.

To examine whether there is a dependence between police presence and reactance score, the chi-square test was applied. The chi-square test tests with a significance level of 5%. If there is no dependence, p-value > 0.05, the null hypothesis is retained, otherwise it must be rejected. In this case, the null hypothesis is that the presence of the police and the determined reactance value are independent of each other.

For a chi-square test to be applied, the following conditions must be fulfilled:

1 The variables are normally distributed

The variable of police presence is normally distributed. Also, the reactance value is to be regarded as normally distributed in this case, since only the achieved value of a person and not whether the person has a better or worse value is of interest.

2 Independence of measurements

This is given here, since both groups consist of different participants and every participant is only present in one of the groups.

3 Each cell has at least a frequency of 5

This information is provided by SPSS.

Since 75% of the cells have an expected frequency less than 5, the credibility of the chi-square test may be doubted, since this may have led to an inaccurate or rather false p-value. Thus, the last requirement for the application of the chi-square test is violated here.

For this reason, the Fisher exact test is used, as it provides reliable results even for a small sample.

Fisher's test yields a two-tailed p-value of 0.447, which is greater than 0.05. Accordingly, the null hypothesis can be retained. This means that there is no significant relationship between the presence of the police and the reactance value.

4.1.2 Results of the reactance test related to the instructional follow-up concept

In the following, the research question "Can the instructional follow-up concept already developed for Crash Kurs NRW also be used to reduce reactance in this changed context?" will be answered. For this purpose, it will be investigated whether a difference exists between the determined reactance values of the participants before and after the follow-up and, if it does exist, how such a difference might arise. By means of the paired t-test, it is first checked whether a significant difference exists. For the paired t-test to be used, the following conditions must be met:

1 Dependence of the measurements

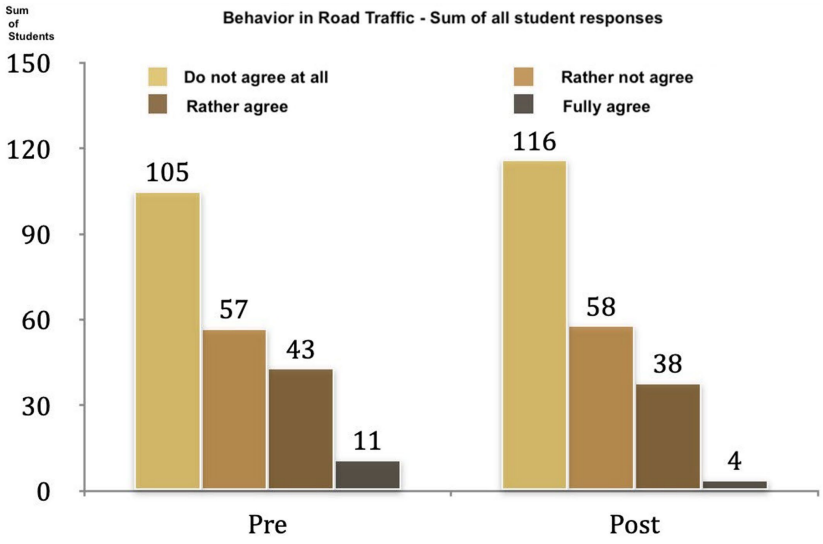

FIGURE 7
Comparison of item responses pretest and posttest in the query section. "Behavioral changes" (source: own representation).

The individual measurements must be dependent on each other. This is the case here, since each participant completed a pretest and a posttest and these could be assigned to the participants by means of an anonymous identifier. This made it possible to create a table with the reactance value of a person before the posttest and the reactance value of the same person after the posttest.

2 The dependent variable is at least interval scaled

In this case, the dependent variable is the reactance value, so this condition is fulfilled.

3 The independent variable is normally distributed and has two expressions

The independent variable in this case is the respective time of the measurements. This corresponds to the pretest before follow-up and the posttest after follow-up.

4 Data should not have outliers.

5 The differences of the data from the different time points should be normally distributed.

The last two conditions could be checked by means of SPSS. For this purpose, the difference between the values from the pretest and posttest was calculated and then generated as a new variable. With the help of this variable, an explorative data analysis was carried out to check both conditions.

This yielded the result that there were no outliers in the data set. Thus, the fourth condition was also fulfilled. To check the differences of the pre- and posttest values for normal distribution, the Shapiro–Wilk test was applied. The result can be seen in the Supplementary Table S1.

The Shapiro–Wilk test yields a value of 0.115. Since this value is greater than the significance level (0.05) with which this test tests, it means that the differences are approximately normally distributed. Thus, all requirements are met to be allowed to use a paired *t*-test. The result of this paired *t*-test can be seen in the Supplementary Table S3. Since a significance level of 0.05 was used to test and $t(23) = 0.551$, $p = 0.587$ exceeds the critical value, it can be determined that there is no significant difference between the pretest and posttest reactance values.

4.1.3 Results of behavior change related to instructional follow-up

The first step was to compare the participants' responses in the "Behavior in road traffic" section between the pretest and the posttest. The results shown in Figure 7 make it clear that the ideal answer for all items should be "strongly disagree," in line with the message conveyed during the classroom follow-up. Figure 7 shows a summary of the results for all nine items. Accordingly, there was a successful change in behavior, as the participants no longer agreed with the statements of the items after the intervention.

Now that the overall overview of the changes between the pretest and posttest has been presented, the individual items are examined in detail. This examination enables a more precise insight into the specific changes in behavior in road traffic and contributes to the comprehensive analysis of the intervention effects.

This will be analyzed in the further course by determining the transition of the responses from "Agree somewhat" and "Agree completely" in the desired direction. For this purpose, a table was created for both the pre-test and the post-test, documenting the responses of each individual person. The answer "Agree somewhat" was weighted with one point and the answer "Agree completely" with two points. It is also assumed that the answers "Strongly disagree" and "Strongly disagree" correspond to the desired behavior and therefore zero points are awarded for such answers. The difference between the sums of the individual values for each person in both tests can now be used to determine the change.

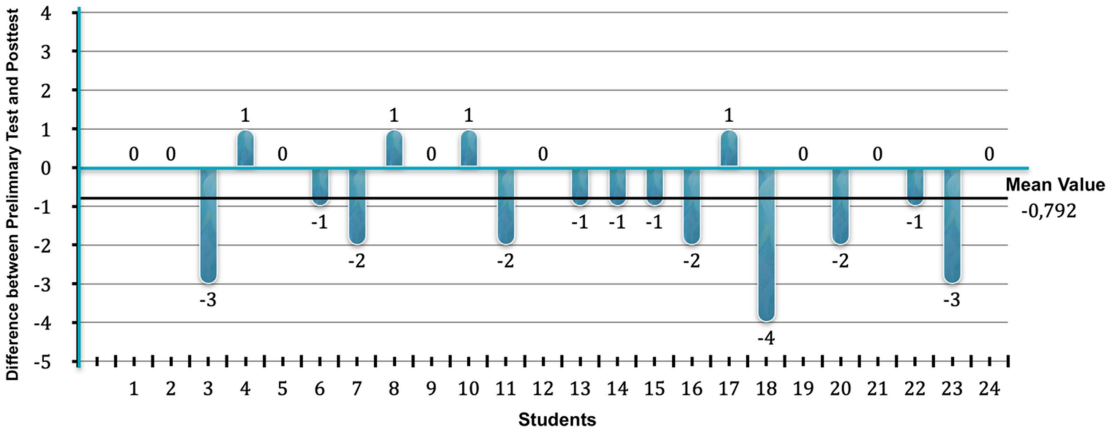

FIGURE 8
Difference in points between pretest and posttest in the "Behavior in road traffic" section (source: own representation).

A positive value signifies that the respective participant "agreed" more often in the posttest than they did in the pretest, indicating an undesired outcome. By contrast, a negative value expresses that the desired effect was produced. A zero indicates, that the ticking behavior remained the same.

Figure 8 already shows that the follow-up led to an improvement in the attitude toward one's own behavior in road traffic. This was checked in concrete statistical terms using the paired *t*-test.

The aforementioned prerequisites four and five from Section 4.1.2 were again checked using SPSS. These showed that there were no outliers in the data set. The Shapiro–Wilk test returned a value of 0.043, which meant the difference in the pre- and postvalues were not normally distributed in this case. However, since the paired *t*-test is relatively robust to violations of the normal distribution assumption, this result could be neglected and the paired *t*-test could still be performed. The result of the paired *t*-test can be found in Supplementary Table S4.

Thus, the scores for ticking consent responses were significantly lower after the posttest than before in the pretest, $t\ (23) = -2.805$, $p = 0.010$. Accordingly, the paired *t*-test confirmed the assumptions based on Figure 6.

Subsequently, the strength of this effect was determined using Cohen's d in SPSS. The statistical measure of the strength of Cohen's effect *d* is shown in Supplementary Table S6.

The result showed an effect size of 0.573. According to Cohen, this corresponds to a moderately strong effect. Therefore, it can be concluded that the conducted follow-up can contribute to a desired change in attitude or behavior. Although not all participants were reached to the same extent, this effect is still statistically significant.

In summary, it can be observed that due to varied reactions within a target group despite identical fear appeals, it can be assumed that not all female and male students were reached equally. This is influenced, among other factors, by gender-specific differences. In the analysis of behavior change, it was evident that a higher percentage of female students (60%) were reached compared to male students (~43%). This aligns with the expectation that women tend to react more sensitively to fear appeals and are more likely to comply. Surprisingly, male students exhibited a "stronger" change, despite literature suggesting that men usually resist fear appeals involving physical threats.

The dependence between gender and behavior change was further investigated using the Chi-square test. The null hypothesis, stating that gender and behavior change are independent, was retained as the Chi-square test yielded a value of 8.77. Due to expected frequencies smaller than 5 in all cells, the exact Fisher's test was employed. The two-tailed *p*-value was 0.110, and as it is greater than 0.05, the null hypothesis remains. Therefore, no significant relationship between gender and behavior change could be established.

Overall, this suggests that a desired improvement was achieved in half of the female and male students. Consequently, such a program for traffic accident prevention in schools appears to be meaningful.

Following the analysis of the individual items, Cronbach's alpha can be calculated to check the internal consistency of the data collected. The assessment of reliability ensures that the items in the survey represent a reliable measurement of the construct under investigation. This step deepens our understanding of the stability and accuracy of the information collected and enables a well-founded interpretation of the overall results.

The calculated Cronbach's alpha values provide an assessment of the internal consistency of the items in a scale. In this case, the Cronbach's alpha for the raw items is 0.675 and for the standardized items 0.708, whereby the scale consists of nine items in total.

In general, a Cronbach's alpha value of over 0.7 is regarded as an indicator of acceptable to good internal consistency. In your case, both values are in this range, which indicates that the items in the scale correlate with each other and measure the underlying construct consistently. The slightly higher value for the standardized items could indicate that the consistency of the scale was slightly improved after standardization. Overall, however, the available values indicate that the scale has an acceptable internal consistency (see Table 2).

Having looked at the reliability of the items, we now take a look at the mean ratings for each item. This allows for a more detailed analysis of the specific aspects of road behavior under investigation and helps to paint a more comprehensive picture of the results (see Table 3).

TABLE 2 Calculation of Cronbach's alpha in relation to all nine items.

Reliability Statistics	
Cronbach's Alpha	0.675
Cronbach's Alpha for Standardized Items	0.708
Number of Items	9

TABLE 3 Calculation of the mean values "Behavior in road traffic" for all 9 items.

	Item (N=24)	Mean	Standard Deviation
1	Having a beer and then driving is still okay	2,33	0.91
2	If the traffic light turns red, I can quickly step on the gas	1,83	0.76
3	For short distances, I don't need to fasten my seatbelt	1,12	0.44
4	Riding an E-scooter with two people is cheaper	1,12	0.72
5	Typing a message quickly at the red traffic light is okay	1,54	0.90
6	Going up to 20 km/h over the speed limit is okay, as it doesn't result in points	2,29	1,09
7	I am against the state introducing new methods for safety checks in traffic	2,41	0.97
8	I like to react to bans with a "Now even more so" attitude	1,20	0.41
9	I'm not interested in all these topics, as I do what I want anyway	1,25	0.53

The overall mean values confirm the indications of changes in the research results presented.

1 mean value of the pretest of the control group without police ($N = 11$): 1.93

- This value represents the average level before any intervention or treatment in the control group.

2 mean value of the pre-test of the comparison group with police ($N = 13$): 2.28

- This is also the average score before the intervention, but in the comparison group that experienced the police intervention.

3 mean value of the post-test ($N = 24$): 1.70

- This value shows the average level after the intervention in both groups, regardless of the type of intervention.

The findings indicate that the intervention had significant positive effects on the reactance values. This is supported by the statistically significantly lower mean score in the posttest compared to the pretests. Some items of the safety behavior scale (see Table 4) showed also positive effects, but this does not apply to the entire scale.

4.1.4 Results on the effectiveness of the individual exercise tools

Table 5 shows the percentage responses to a series of questions that were asked at a road safety event. The questions can be assigned to specific areas of competence: Questions 1 to 3 cover the competence area of recognizing and assessing, while questions 4 to 6 cover the competence area of experiencing and evaluating. Questions 7 to 9 reflect the competence area of testing and implementation, while question 10 addresses the area of motivation to change.

The answers to these questions offer a differentiated insight into the various competence dimensions of the participants in relation to road safety. The evaluation enables an assessment of the effectiveness of the content presented on the various aspects of safety competence and clarifies the extent to which the event has had an influence on safety awareness, knowledge transfer and motivation to change behavior in road traffic.

The comparison between the pretest and posttest suggests that educational interventions and practical experience can have an influence on participants' attitudes and opinions on various aspects of road safety. In particular, there was a positive change in the rejection of risky behaviors such as drinking and driving and speeding at red lights in the posttest. This suggests that the educational measures implemented may have been effective and led to an improved understanding of traffic risks.

The data also indicates an increased awareness of the effects of drinking and driving, particularly through experiential approaches such as wearing intoxicated goggles. In addition, positive responses to discussions and role-play show that interaction with other participants or hands-on experiences can promote learning effects.

However, it should be noted that changes in the willingness to take risks are also recognizable, such as the tendency to react to prohibitions with "now more than ever." Further differentiated analysis is required here in order to understand whether these changes are beneficial or detrimental to road safety.

In summary, the data point to the diverse effects of educational measures on attitudes, perceptions and behaviors in the context of road safety.

These findings are consistent with the results of a previous study of school students, as documented in a previously published article at https://doi.org/10.3389/fpsyg.2022.1046403 (von Beesten and Bresges, 2022). This suggests that the implemented form of follow-up has brought about positive changes in terms of competence behavior in road traffic.

The additional qualitative evaluations of the audio description in this study further deepen and underpin this positive effect.

TABLE 4 Result of the "danger scale" exercise, sorted according to the filing categories of the Likert scale.

Overview of Hazard Scale Results

0 = not dangerous

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1. The pedestrian traffic light just turns green, and I quickly walk across.

1 = less dangerous

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1. I bought cabinets at IKEA and load them onto the back seat.
2. I love listening to loud music while driving.
3. With a fever and headache, I quickly drive to the pharmacy.
4. Riding a two-person electric scooter.
5. Riding a bicycle across the pedestrian crosswalk.
6. Changing lanes in the car next to a truck.
7. Turning right and looking very carefully and for a long time to the left to check if anyone is coming.
8. Writing a text message while walking.

2 = more dangerous

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1. The prescribed speed limit is 30 km/h, but I only drive 50 km/h.
2. I've only had a small beer; I can still drive well.
3. In traffic jams, I quickly check my phone.
4. At the red traffic light, I quickly check my phone.
5. I take Ritalin and regularly drive a car.
6. As a pedestrian, I walk quickly between cars at the crosswalk.
7. Jumping over the coupling of the tram.
8. Walking behind the train across the tracks.
9. Riding an electric scooter through a pedestrian zone.
10. Riding a bicycle past a truck on the right.
11. Riding a scooter on the sidewalk.
12. As a pedestrian, I walk quickly between cars at the crosswalk.
13. Quickly checking my phone in front of the red light.
14. I want to drive my 5 friends home, even though I only have 4 seats.
15. Enjoying looking at billboards while driving by.
16. Pulling over on the highway because I feel sick.
17. Merging just in front of the truck when entering the highway.
18. Changing lanes to the right just before my exit in front of the truck.
19. Pressing the brake to scare my tailgater because he annoys me.
20. Driving next to a truck in a construction zone.
21. Walking across the road during a traffic jam to see when it will continue.
22. Barely stopping in time in a traffic jam and not looking in the rearview mirror.

3 = dangerous

---

1. The sun blinds me from the front, and I briefly close my eyes.
2. The pedestrian traffic light just turns red, and I quickly walk across.
3. I don't buckle up because I'm only driving a short distance.
4. My girlfriend is pregnant and doesn't buckle up because of that.
5. I've only smoked a little weed; I can still drive well.
6. The car in front of me stubbornly drives on the left side. I drive closely to show that I want to pass.
7. Riding a bicycle against the direction of traffic.
8. Riding a bicycle and changing lanes between cars.
9. If I drink something, I better take the electric scooter.
10. Crossing the street directly in front of a truck.
11. My phone has fallen into the footwell, and I pick it up.
12. I'm alone on a street at night and drive through a red light.
13. Jogging across the pedestrian crosswalk without looking because I have the right of way.
14. I've only smoked a joint; I can still drive a car.
15. Parking and quickly opening the car door because I'm in a hurry.
16. I need to sneeze and let go of the steering wheel.
17. I missed my exit and quickly drive over the restricted area.

Source: own representation.

TABLE 5 Results of the posttest on the exercise tools, $n = 24$.

Question	Yes (%)	No (%)	No Response (%)
1. I feel safer because I now know more than before	72.0	24.0	0.0
2. I received good advice in the discussion	95.8	4.2	0.0
3. I now see road traffic with different eyes	41.7	58.3	0.0
4. I am now more aware of alcohol and drugs	87.5	12.5	0.0
5. I have learned the effects of alcohol on road safety	91.7	8.3	0.0
6. I did not know before how alcohol could affect my body	12.5	87.5	0.0
7. I have learned how to end such a situation for myself	95.8	4.2	0.0
8. The event will influence my future driving behavior	72.0	24.0	0.0
9. I would now have enough courage to ask the driver to stop	100.0	0.0	0.0
10. I want to change and behave more safely	66.7	33.3	0.0

Source: own representation.

TABLE 6 Comparison of the research groups at the exhibit, group 1 without police, group 2 with police.

	Control group with police	Comparison group without police	Total
Understanding physics		6,5%	4,9%
Generate knowledge	10,0%	3,2%	4,9%
Recognition in everyday life transfer	20,0%	6,5%	9,8%
Showing emotion	30,0%	29,0%	29,3%
Finding solutions			
Compensation actions	40,0%	54,8%	51,2%
Total	100,0%	100,0%	100,0%
Documents/Speakers	1 (50,0%)	1 (50,0%)	2 (100,0%)

Source: own representation.

4.2 Results of the qualitative methods

4.2.1 Results of the observations on the exhibit

A comparison of the two research groups in terms of behavior at the exhibit could be presented in the evaluation with the help of a cross-table the following results (see Table 6).

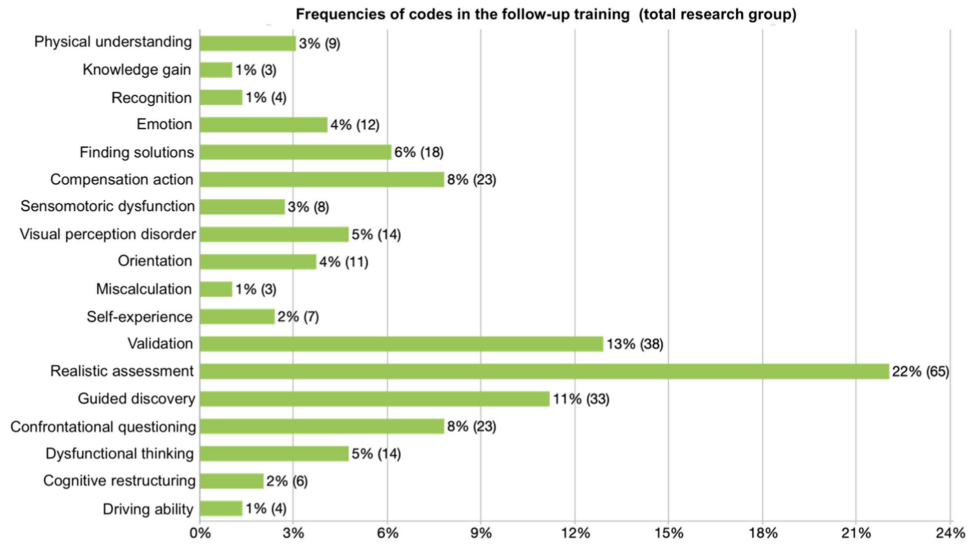
The overview shows that through the briefing and the explanations from the police, the gain of knowledge in the topic of traffic safety was significantly higher. Already during the first explanations of the exhibit, the subject matter, the classification of the topic and also the traffic accident in the local events were more strongly recognized and could thus be better assigned to one's own life context. Defense mechanisms due to emotional bias as a result of personal familiarity with the accident, which was equally present in both groups, did not require as many compensatory action strategies in the group moderated by the police as in the group without moderation. The reason for this could be a high level of acceptance of the police officer's expertise and credibility in communicating the traffic-related issues. During the quiet conversations among themselves, participants in the unmoderated group focused more thematically on what was familiar to them in the context of the professional situation of their constellation. These included physical concepts. By contrast, these were not addressed in the police facilitated group. This implies that purposeful moderation on physics related topics opens up different solution paths than moderation by police officers, who tend to provoke normative and rule-conforming behavior in the group. Both approaches are promising. It would be worth considering alternating both approaches in a holistic course concept in order to reach a broader target group overall and to uncover and discuss a greater variety of possible solutions.

4.2.2 Results of the instructional follow-up

The analytical evaluations of the observations in the classroom follow-up are presented in Table 7.

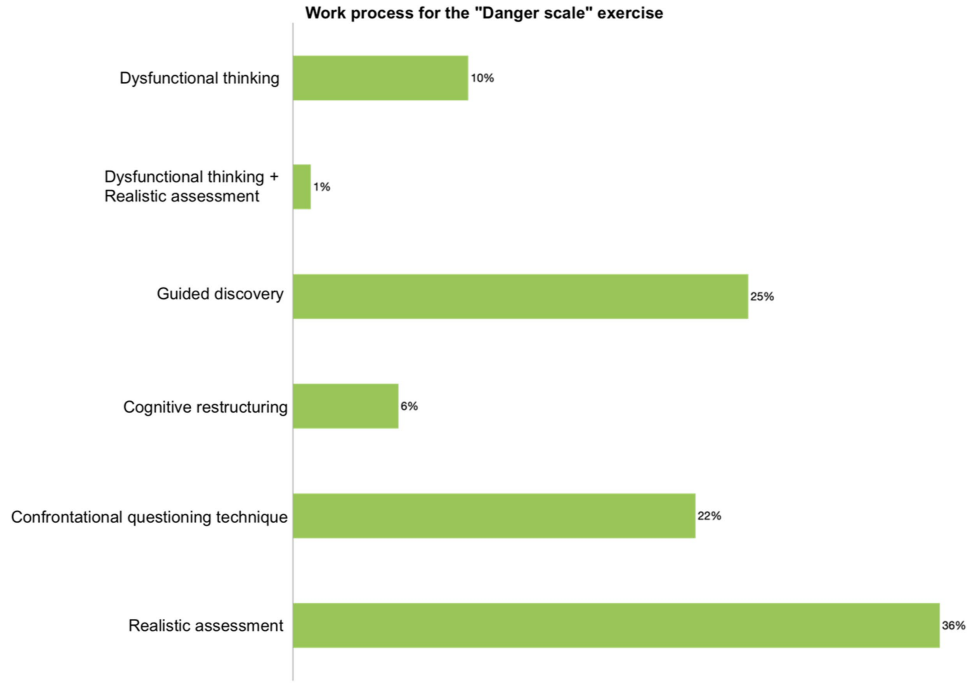
This overview shows that the group of participants from a technical vocational college was already able to make realistic assessments of traffic situations in many cases. Concordantly, the proportion of dysfunctional thinking was low. The following overview demonstrates that due to prior knowledge, including their knowledge of physics, only little knowledge could be gained. This was discovered during the development of the danger scale, a filing system based on the principle of a Likert scale (see Table 4).

TABLE 7 Overview of the coding in the instructional follow-up.



Source: own representation.

TABLE 8 Work process for the "Hazard Scale" exercise.



Source: own representation.

It can be seen that only a few cards were placed in the "Rather Not Dangerous" area and only one card in the "Not Dangerous at All" area. These cards, along with other topics, were part of the open discussion that followed. Dysfunctional thought processes were revealed via processes of confrontational questioning and guided discovery. Cognitive restructuring techniques led to new realistic assessments that supported existing realistic assessments. These findings are supported by previous research (https://doi.org/10.3389/fpsyg.2022.1046403, von Beesten and Bresges, 2022) in school, since the same cards were classified as supposedly harmless and only through discussion and exchange could the underlying danger be detected. Table 8 shows the statistical evaluation of this process:

The exercise with the intoxication goggles yielded the following results (see Table 9).

The answers to the research questions are as follows:

Q1: Does the modified concept of exhibiting a damaged car generate less reactance than Crash Kurs NRW?

A1: Yes, the post-processing approach resulted in significantly lower reactance values.

Q2: Does the presence of police lead to increased reactance?

A2: No, the presence of the police does not change reactance.

Q3: Can the instructional follow-up concept be successful in terms of a targeted change in behavior?

A3: Yes, the instructional follow-up concept can successfully contribute to a change in behavior.

Q4: Is the exhibit of an accident car suitable for teaching physics topics?

A4: In the case of a targeted presentation on physical topics, the exhibit is suitable to explain and illustrate physical topics.

These results demonstrate that particular importance was attached to the visual perception disorders, the motor dysfunctions, and the associated misjudgments in the space-location structure. These are exactly those physical functions that are targeted by the intoxication goggles in the exploration.

The role play "The last two minutes" produced the following results (see Table 10).

Evidently, the group, which was equipped with a very realistic assessment, was able to come up with a good solution and was only able to achieve minor additional gains in knowledge.

4.3 Summary of the results

By considering all the statistical results of the online surveys and observations, calculated both qualitatively and quantitatively, as well as the questions raised on site in the focus groups, it was possible to reflect well on the research questions. The results make it possible to answer them.

5 Discussion

5.1 Discussion of the scientific quality criteria

Compliance with scientific quality criteria plays a central role in the methodological reflection of scientific studies. These criteria serve to ensure the security, transparency, reliability and validity of scientific findings (Häder, 2010, p. 108). In the context of this research work, a differentiated consideration of quality criteria is necessary, focusing on two key aspects:

- Quality criteria of quantitative research: quantitative research methods are characterized by the systematic collection and evaluation of numerical data. The quality of such research approaches is assessed on the basis of various criteria such as validity, reliability and objectivity. Validity refers to the accuracy and appropriateness of the measured constructs, while reliability concerns the consistency and reliability of the measurements. Objectivity refers to the extent to which the results are independent of the individual assessments of the researchers (Häder, 2010, p. 108).
- Quality criteria for qualitative research: In qualitative research, the focus is on interpretation and understanding processes. Quality criteria for qualitative studies include criteria such as reproducibility (the possibility of retracing the research steps), transferability (the generalizability of the results to other contexts), consistency (the internal coherence of the results) and reflexivity (the researcher's critical examination of his or her role and influence on the study) (Häder, 2010, p. 108).

Addressing these quality criteria helps to ensure the methodological quality of the research work and to make its results reliable and comprehensible. Care should be taken to ensure that the criteria are adapted to the specific requirements of quantitative or qualitative research.

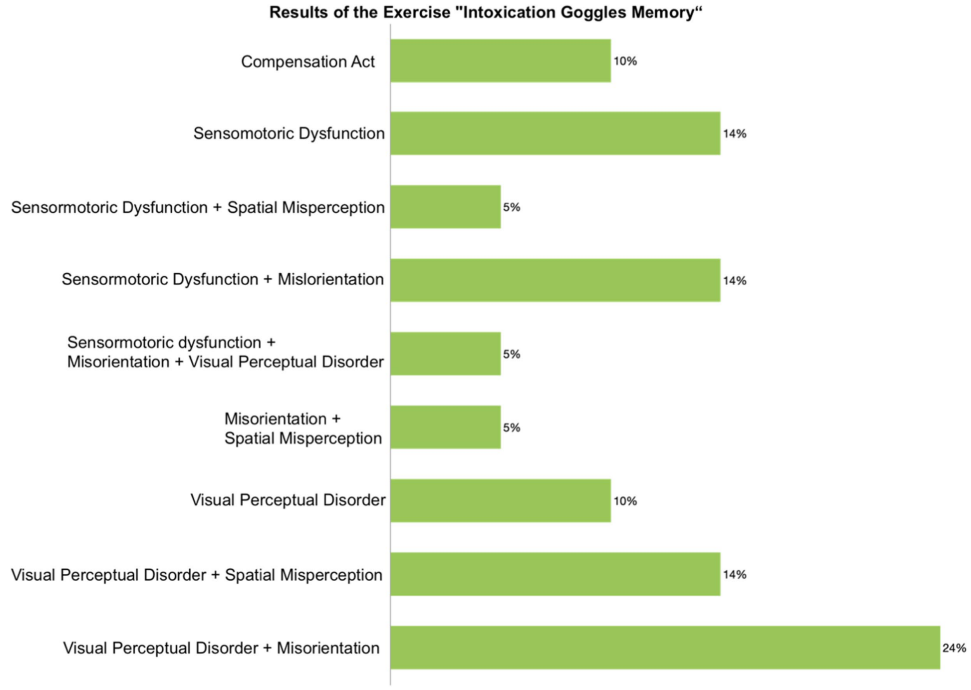
5.1.1 Quality criteria of quantitative research

The aim of measurements in quantitative research is to collect the most accurate and error-free measured values possible. However, this goal is hardly ever fully achieved in research practice. The "classical test theory" allows very simple definitions of quality criteria for measurement. According to this, measurements should be as objective, reliable and valid as possible, and economical, comparable and useful for practical implementation. Objectivity and reliability are minimum requirements for a measurement instrument (Häder, 2010, p. 108), although the main goal is to construct instruments that are as valid as possible.

When evaluating a teaching module, this approach is impeded insofar as prevailing individual perspectives are reflected in subjective judgments, perceptions, attitudes, and views in the survey that affect validity (Schubarth, 2006, p. 282).

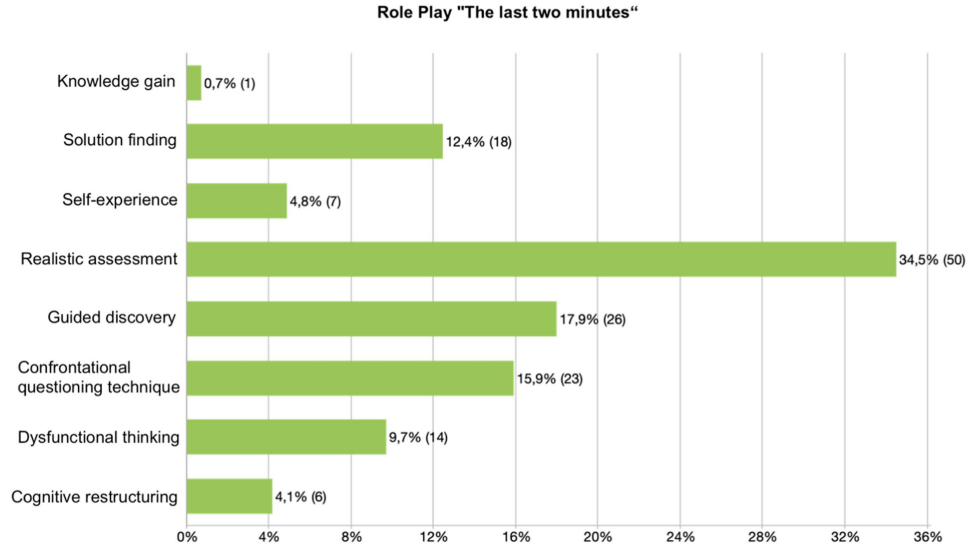
Since neither the follow-up *Crash Kurs NRW* nor the project of exhibiting a damaged car has any existing precedent, it was not

TABLE 9 Results of the "intoxication goggles memory" exercise.



Source: own representation.

TABLE 10 Results of the role-play "The last two minutes".



Source: own representation.

possible to rely on already validated measurement instruments. The creation of the measuring instruments used were partly adapted to the context of the follow-up of this project and it was not possible to employ already validated existing questionnaires. Thus, despite having produced valid results, they did not fully meet the quality criteria in all areas, as scientifically required.

Furthermore, it must be acknowledged that the surveys were conducted at only one vocational college so far and the associated limited selection of participants could neither be randomized nor representative. Thus, these surveys provide information only as it relates to a product that has yet to be introduced on a greater scale. Therefore, the highest possible degree of fit exists only for

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TABLE 11 Overview of the quality criteria of quantitative research and its fulfillment indexes.

Quality Criteria	Definition	Compliance Index
Objectivity	is the extent to which a study result cannot be influenced by the study director in its execution, evaluation and interpretation, or when several experts arrive at concordant results. This means that different experts must not achieve different results, neither in the performance nor in the evaluation and interpretation. The objectivity of execution requires that the result of the examination remains uninfluenced by the user. Objectivity of interpretation requires that individual interpretations must not be included in the interpretation of a result.	Implementation objectivity can be assumed here, since the online surveys of the participants were carried out by the author of this work without any influence. The objectivity of evaluation and interpretation is also given, since the statistical program SPSS has provided the facts.
Reliability	indicates the reliability of a measurement method. An examination is described as reliable if the same result is obtained when the measurement is repeated under the same conditions and on the same objects. It can be determined, among other things, by repeating the examination (retest method) or by another equivalent examination (parallel test method).	Reliability can be assumed with regard to the online surveys of the participants following the follow-up module, as this research round is the second of its kind and produced comparable results to the first research round. The teaching methods applied were the same, the learning object was a comparably similar one in a modified form.
Validity	is the most important test quality criterion, because it indicates the degree of accuracy with which a test captures what it is supposed to capture. Validity is checked using correlation with an external criterion. Objective and reliable instruments do not have to be valid at the same time. Validity can only be assessed in relation to certain other measurements. Different types of validity are distinguished: Construct validity, criterion validity, content validity, ecological validity.	The author took the aspect of validity into account in that the interviews and observations in the surveys were precisely aligned with the initial problem posed. The entire research process intends a direct confrontation with the introductory problem and the research questions.

Source: own representation.

previously studied needs. However, parallels are very clearly recognizable here.

The following overview explains the quality criteria and its fulfillment indices of the quantitative research part (see Table 11).

5.1.2 Quality criteria of qualitative research

In contrast to quantitative research, no generally accepted quality criteria have yet been established in qualitative research; rather, various differentiated proposals for the quality assessment of the qualitative methodological approach are available (Strübing et al., 2018, pp. 83–100).

The application of the classical quality criteria from quantitative research (objectivity, reliability, validity) to qualitative research is largely rejected. This is justified by the particularities of the qualitative methodological procedure, the epistemological positions on which they are based, as well as ethical and practical aspects of research. Among the multitude of proposed aspects for quality production and assessment, the overarching quality criteria of transparency, intersubjectivity, and scope appear to be particularly central (Strübing et al., 2018, pp. 83–100).

Kuckartz has developed various methods and techniques for qualitative research that focuses on the understandability of human behavior, the context in which it occurs, while keeping the perspectives of the subject open. The researcher is allowed to discover new aspects during the research and adapt the research question, developing theories and ideas in the process. Qualitative research can combine different methods in this process. The characteristics of qualitative research according to Kuckartz show that qualitative research aims to collect and interpret data that cannot be expressed in numbers, and that it focuses on a deep understanding of the phenomenon rather

TABLE 12 Overview of the quality criteria of qualitative research and its fulfillment indices, according to Kuckartz.

Quality Criteria	Definition	Compliance Index	Quality Criteria	Definition	Compliance Index
Transparency and comprehensibility	Since qualitative research involves a wealth of research decisions and the use of methods always means the development of methods, the entire process must be adequately documented and explained. It must also be made comprehensible how the data were evaluated and interpreted.	This was sufficiently observed and provided via the presentations of the tables and figures in the methods section and explained in the results section.	Triangulation	To increase the validity of the research results, different methods and data sources should be used to verify and validate the results.	This must be verified via further research and additional research runs. Upcoming crash course stage events as well as prevention campaigns with the exhibit are suitable for this purpose.
Intersubjective comprehensibility	Research findings should be comprehensible to other researchers and replicable in other contexts.	The results are made transparent and are thus comprehensible for other researchers. The post-processing curriculum is to be made feasible for others in a future publication step. Due to the change of the project that has already taken place here, on whose application the post-processing concept was equally effective, a replicability can be assumed.	Saturation	Data collection should continue until no new information or findings can be obtained.	This needs to be verified via further research and additional research runs. For this purpose, both upcoming crash course stage events and other emotionalizing prevention campaigns with the exhibit can be applied.
Reflexivity	Researchers should be aware that their own prior assumptions and experiences may influence their research. They should therefore critically reflect on how their own assumptions influence the research and also document this reflection in their work.	The experiences of the moderators, especially the police, have been incorporated into the concept. This was taken into account in the quantitative and qualitative evaluation and was given its own evaluation direction in the criteria of reactance and compensation.	Relevance	The research should have clear relevance to the research question and be built on a theoretical foundation.	The research is designed for the suitability of the instructional follow-up of the prevention campaign Crash Course NRW, or comparable emotionalizing prevention campaigns and therefore has a high relevance for the topic. The theoretical basis was presented in this research paper.

Source: own representation.

than focusing on statistical significance. The six research criteria according to Kuckartz were applied to present research and answered as follows in his fulfillment indices (Kuckartz, 2016, pp. 145–154) (see Table 12).

5.2 Limits of the study

A pilot study can provide important insights and at the same time open doors for further research by highlighting certain limitations and potential areas for improvement (Gaus and Muche, 2017, p. 459). One limitation present here is the limited sample size of $n = 24$, which affects the generalizability of the results. Therefore, a next phase of research should involve increasing the sample size to allow for more representative conclusions.

Furthermore, pilot studies could capture short-term effects while long-term effects remain unconsidered (Gaus and Muche, 2017, p. 459). As a result, a further development of the present study should be to conduct a long-term study with several cohorts and interviews at several consecutive time points (post-survey 1, 2, 3 …) of the accident car in order to understand the longer-term developments in the participants more precisely.

In addition, pilot studies have the limitation that the effects may vary in different population groups (Gaus and Muche, 2017, p. 459). Therefore, an extension of the research should be to expand the study to different populations (age groups, school types) to identify possible differences.

Finally, new questions or hypotheses may arise from the pilot study that require further research to explore these aspects in more depth. Overall, these identified research limitations serve as a guide for the further development and refinement of the research.

The present study was able to prove that a campaign with an accident car as an exhibit generates less reactance than the stage campaign *Crash Kurs NRW*. It was also able to prove that the follow-up is suitable for minimizing reactance. However, it must be considered that the target group had little reactance beforehand. As a result, further research focusing on different target groups may be necessary: younger target groups with less prior knowledge about road safety and even more willingness to engage in risky behavior would be desirable for further test runs.

5.3 The research gap

The study did not conduct any surveys on participants with physical or psychiatric impairments that would have had a lasting effect on road safety, such as personality disorders or organic neurological disorders (e.g., malformations, epilepsy, schizophrenia). Thus, no findings could be obtained as to whether the concept also has an effect on psychological or psychiatric disorders, or whether it can make people more aware of any physical dysfunctions and thus help to clarify and stabilize misconduct.

5.4 Comparison with other research

In the previous research work, on the one hand, the instructional follow-up of the stage event *Crash Kurs NRW* was put under the aspect of minimizing reactance. On the other hand, an improvement of behavior with regard to road safety through the follow-up concept was put to the test. Both could be confirmed in the last research.

The main question posed by this research work was whether a comparably emotionalizing campaign could generate less reactance and then initiate the same successful behavioral change for traffic safety with the same follow-up concept. Both research questions could be positively confirmed.

6 Conclusion and outlook

The results of the various research questions provide a comprehensive conclusion on the effectiveness of the modified concept of an accident car exhibit and the instructional follow-up concept.

With regard to the research question of whether the modified concept of the accident car exhibit generates less reactance than the previous approach, the results clearly show that the follow-up concept leads to lower reactance values. This suggests that the modified approach to teaching accident prevention and safety measures is met with a positive response and generates less reactance than the previous approach.

The research question of whether the presence of the police leads to increased reactance is refuted by the results. It is shown that the presence of the police has no significant effect on reactance scores. Regardless of the presence of the police, participants show similar reactions and are not more or less resistant.

Regarding the research question of whether the instructional follow-up concept can successfully contribute to a desired change in behavior, the research results provide positive findings. It can be seen that the follow-up concept is effective in achieving behavioral change with regard to accident prevention and safety. Thus, the educational treatment of the topic after the accident event can contribute to the participants adapting their behavior and making safer decisions.

The research question as to whether the accident car exhibit is suitable for addressing physics topics in the classroom can also be answered in the affirmative. Under the condition of goal-oriented moderation, it is shown that the accident car exhibit can be used as a visual aid to vividly convey and explain physical aspects. It enables the students to better understand concepts of physics related to traffic accidents.

In summary, the results suggest that the modified concept of exhibiting a car that was damaged in an accident has a positive effect on participants' reactance, while the presence of the police shows no significant effect on reactance. The instructional follow-up concept appears to successfully contribute to a change in behavior, and exhibiting the damaged car, under purposeful facilitation, is suitable for addressing physics related topics in the classroom. These results suggest that the new concept and the use of the exhibit can be effective methods to promote accident prevention and safety awareness.

Further research can support these findings and contribute to the advancement of the core curricula for physics education, as well as meaningfully integrate traffic accident prevention as a mandatory element in schools.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the studies involving humans because research took place in accordance to state law. No personal data was recorded. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

SB: Conceptualization, Formal analysis, Visualization, Writing – original draft. AB: Conceptualization, Formal analysis, Methodology, Resources, Validation, Writing – original draft, Writing – review & editing. DL: Data curation, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2023.1276380/full#supplementary-material

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3.2.3 Wirksamkeit geeigneter Lehrmethoden zur Vorbereitung von Lehramtsstudenten auf die Vermittlung verkehrssicherheitsrelevanter Inhalte

Einleitung: Diese Studie präsentiert einen neuartigen Ansatz zur Lehre der Verkehrsphysik, der darauf abzielt, Unfälle durch eine ganzheitliche Herangehensweise zu verhindern. Dabei werden umfangreiche Analysen, empirische Umfragen und die Entwicklung von Prototypen eingesetzt, um Studierende aktiv in die Identifizierung, Analyse und Lösung von Verkehrsproblemen einzubeziehen, insbesondere im Hinblick auf die Sicherheit im öffentlichen Raum.
Die angehenden Lehrenden sollen hier auf ihre zukünftige curriculare Verpflichtung zur Verkehrsprävention an den Schulen vorbereitet werden.

Methoden: Die Methodik dieses Ansatzes basiert auf der Anwendung theoretischer Konzepte der Verkehrsphysik in realen Verkehrssituationen. Schulen dienen dabei als Testumgebungen, um bereits in einem frühen Stadium das Bewusstsein für Verkehrssicherheit zu schärfen. Studierende angehender Lehrämter führen Verkehrsraumanalysen durch, um potenzielle Gefahrenpunkte zu identifizieren. Qualitative Forschungsmethoden wie Design Thinking und Interviews werden integriert, um Empathie zu fördern und tiefere Einblicke in die Erfahrungen der Verkehrsteilnehmer*innen*innen zu gewinnen (Grots, A., Pratschke, M., 2009).
Eine umfassende schulische Aufklärung über Verkehrssicherheit ist entscheidend für die Entwicklung sicherheitsbewussten Verhaltens bei jungen Menschen. Klimmt et al. (2015) betonen die Bedeutung von regelmäßigen und gut strukturierten Unterrichtseinheiten zur Verkehrssicherheit, um Schüler*innen kontinuierlich zu sensibilisieren und zu verantwortungsbewusstem Verhalten zu erziehen. Die pädagogischen Prinzipien, die in dieser Studie angewendet werden, sind stark von den Ideen von Dewey beeinflusst, der betont, dass Bildung demokratische Werte fördern und zur Entwicklung kritischen Denkens beitragen sollte (Dewey, 2016). Diese Prinzipien sind zentral für die Entwicklung von Lehrmethoden, die nicht nur theoretisches Wissen vermitteln, sondern auch praktische Fähigkeiten und Verantwortungsbewusstsein im Kontext der Verkehrssicherheit fördern.
Die Interessen der Schüler*innen spielen eine wesentliche Rolle für den Lernerfolg im Physikunterricht. Muckenfuß (1995) hebt hervor, dass Unterricht, der sich an den Interessen der Schüler*innen orientiert, signifikant zur Motivation und zum Lernerfolg beitragen kann. Dies ist besonders wichtig bei der Vermittlung von verkehrssicherheitsrelevanten Inhalten, da ein praxisnaher und interessensbasierter Unterricht das Engagement und die Verantwortungsübernahme der Schüler*innen fördert.
Häußler et al. (1998) identifizieren mehrere Faktoren, die das Interesse der Schüler*innen an Physik bestimmen, darunter die Relevanz der Themen für das tägliche Leben und die

Möglichkeit, praktische Erfahrungen zu sammeln. Diese Erkenntnisse sind besonders relevant für die Entwicklung von Lehrmethoden zur Verkehrssicherheit, da sie darauf hinweisen, dass ein kontextualisierter und praxisorientierter Unterricht das Interesse und das Verständnis der Schüler*innen für physikalische Prinzipien im Straßenverkehr fördern kann.
Ein kontextorientierter Physikunterricht, wie von Nawrath (2010) vorgeschlagen, betont die Bedeutung der Einbettung physikalischer Themen in lebensnahe Kontexte, um das Verständnis und die Relevanz für die Schüler*innen zu erhöhen. Diese Herangehensweise kann besonders effektiv sein, um verkehrssicherheitsrelevante Inhalte zu vermitteln, indem sie die physikalischen Prinzipien direkt mit den alltäglichen Erfahrungen der Schüler*innen im Straßenverkehr verknüpft.

Fazit: Die gewonnenen qualitativen Daten aus den Interviews bilden eine solide Grundlage für die weitere Analyse und Gestaltung präventiver Maßnahmen. Studierende leiten durch eine ganzheitliche Betrachtung der Verkehrsteilnehmer*innen perspektiven gezielte Strategien zur Verbesserung der Verkehrssicherheit ab und entwickeln Prototypen, die innovative Lösungen demonstrieren und eine Vision für zukünftige Implementierungen bieten. Darüber hinaus wurde ein Analyse- und Bewertungsinstrument für Modulprüfungen entwickelt, um klare und objektive Kriterien festzulegen, die die Qualität der Prüfungen gewährleisten.

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The effectiveness of teaching methods for preparing teacher education students to teach road safety-related content

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Introduction: Road traffic accidents account for numerous fatalities worldwide, disproportionately affecting vulnerable groups such as children. To counteract this trend, innovative educational approaches are essential, integrating road safety into school curricula. This study presents a novel teaching model for student teachers specializing in traffic physics. The model employs a holistic and interdisciplinary approach to foster safety awareness during teacher training and to prevent accidents effectively.

Methods: The teaching approach combines theoretical concepts of traffic physics with real-world applications. Schools serve as testing grounds where prospective teachers conduct traffic analyses, identify hazardous zones, and examine physical laws such as traffic density and speed patterns, alongside psychological aspects like behavioral deviations. Qualitative methods, including design thinking and interviews with road users, promote empathy and provide deeper insights into the challenges of road safety. Prototypes, such as optimized traffic signs and technology-driven safety solutions, illustrate practical applications and solutions.

Results: The active involvement of students in analyzing and resolving traffic issues enhanced their understanding of physical principles. The combination of theory and practice improved hazard perception, risk assessment, and empathy toward road users. The developed prototypes translated learning objectives into actionable safety measures and demonstrated potential for scalable applications. An evaluation tool ensured the objective assessment of learning outcomes, incorporating pedagogical principles and subject-specific standards.

Discussion: The findings emphasize the importance of integrating traffic physics into school education. This context-oriented approach connects learning with students' everyday experiences, fostering cognitive, emotional, and behavioral dimensions of road safety. By involving prospective teachers, the program not only enhances their individual competencies but also contributes to a broader societal impact, improving road safety education. This study outlines an innovative framework for teaching traffic physics that integrates theoretical knowledge with practical application to promote road safety. The model provides a replicable and scalable solution for embedding safety education into school curricula, addressing a critical public health issue effectively.

KEYWORDS

road safety, physics lessons, youth risk in road traffic, design based research, teacher training program, safety behavior

1 Introduction

The global #3500LIVES campaign of the Fédération Internationale de l'Automobile (FIA) is an initiative to improve road safety and reduce the number of road fatalities. The name of the campaign, "#3500LIVES," refers to the fact that around 3,500 people are killed on the roads worldwide every day (ADAC, 2020). The campaign promotes several simple but effective safety measures, such as wearing seatbelts, obeying speed limits, avoiding distractions from cell phones and from driving under the influence of alcohol, and aims to raise awareness of the high fatality rates on the roads and make the public aware of the importance of road safety. Through posters, social media and other means of communication, the safety messages are spread worldwide to reach a wide audience. One of the central themes of the #3500LIVES campaign is the safety of children on their way to school. Children are among the most vulnerable target groups in road traffic worldwide, including in Germany. Their vulnerability results from a combination of factors such as a smaller body size, a limited ability to perceive and assess danger and a lack of experience in road traffic.

In Germany, this problem is being addressed by various national and local initiatives aimed at making the way to school safer for children.

The way to school represents a major potential danger for students, but also for other road users. Children in particular face a variety of challenges in road traffic. Due to their smaller height, it is difficult for them to observe traffic situations clearly. In addition, in the event of a collision, they are hit in particularly sensitive areas of the body such as the head and the torso, which significantly increases their risk of injury compared to adults. Data from the Federal Ministry for Digital and Transport shows that a total of 25,806 children were involved in road traffic accidents in Germany in 2022. Of these, a total of 51 children were fatally injured, 21 of these children were pedestrians and six were cyclists (BMDV, 2023)[1].

It is therefore no coincidence that the task of traffic and mobility education at school is to impart knowledge and promote the skills and attitudes required for responsible participation in road traffic.

There are different approaches to teaching these necessary skills. Organizations such as ADAC and road safety associations offer a wide range of thematic support with corresponding school programs.

One possibility that has received little attention to date is the inclusion of physics lessons.

In fact, the relevance of physics manifests itself directly in the students' lives, yet the school subject of physics has a comparatively low preference among learners (Muckenfuß, 1995, p. 77). It is an obvious assumption that physics lessons are considered so unpopular because there is little overlap between their content and the students' personal interests. It is therefore essential to take measures to optimize the status of physics teaching in school education (Muckenfuß, 1995, p. 20–22).

Physics acts as a fundamental explanatory discipline for phenomena that every individual encounters in their everyday life. Accordingly, topics that are directly linked to students' everyday lives should be examined in class in order to familiarize them with the underlying physical concepts. The aim is to increase the motivation and interest of learners in physics lessons through a strong connection to their own lives. This approach includes context-oriented teaching, which embraces topics from the students' immediate environment and experiences. For context-oriented teaching to work, authentic contexts, a comprehensive learning environment and, above all, the subject framework should be considered (Nawrath, 2010, p. 19).

The following four factors are the best way to predict a student's individual interest in physics:

- The extent of the fascination with technical and natural phenomena.
- Self-confidence in their own performance.
- The subjectively perceived personal importance.
- The perception of the relevance of the subject for their own life (Häußler et al., 1998, p. 125).

This means that if a student agrees with the questions that characterize these factors, then there is a high probability that he or she is also interested in physics topics. Remarkably, gender is not explicitly mentioned among the factors describing interest in physics. The existing gender-specific differences are apparently already adequately described by the four factors mentioned. In other words, individual interest in physics is causally influenced by fascination with technical or natural phenomena, self-confidence in one's own abilities, perceived personal importance and the perception of the relevance of the subject for one's own life, regardless of gender (Häußler et al., 1998, p. 125).

The findings presented here are of particular interest as they can serve as a basis for the development of strategies for optimally adapting the content of traffic physics and traffic accident prevention lessons to the interests of the students. Selecting topics from the field of traffic physics, traffic accidents and accident prevention, ensures that the subject matter will be appealing to the students. This underlines the relevance of focusing more on everyday topics in physics lessons that deal with the phenomenon of mobility and human behavior in connection with traffic situations. The University of Cologne has developed a teaching module to integrate these topics into physics lessons in an appealing and age-appropriate way and to effectively convey safety-related messages. This module is part of the future-oriented training of prospective teachers and prepares them specifically for the implementation of this task. This article presents this teaching module "Traffic Physics", its approach and objectives. In this context, grading criteria have been developed so that teachers can also assess students for this part of their school education in the future, analogous to the other curricular topics of physics teaching, in order to achieve the educational goal.

The authors assume that the proposed concept offers innovative didactic approaches for educators by not only integrating traditional road safety programs but also incorporating novel methods to promote self-reflection and to embed road safety content early in the school curriculum. This combination enables educators to prepare young people for the challenges of road traffic in a holistic manner by addressing both cognitive and behavioral aspects of road safety. The concept aims to enhance students' self-efficacy and to foster sustainable behavioral change that goes beyond mere knowledge acquisition.

1 https://www.destatis.de/DE/Presse/Pressemitteilungen/Zahl-der-Woche/2023/PD23_33_p002.html

2 Theoretical framework

2.1 General framework conditions

Teaching specifications are an essential element of a modern, comprehensive overall concept for developing and ensuring the quality of schoolwork. Studies show that the evaluation of road safety education courses aimed at children is carried out with some care. However, this is not the case for courses aimed at young people and therefore young drivers (Faus et al., 2023). Moreover, of the few evaluations that have been carried out, most relate to prevention programs for children. However, there is insufficient data available on prevention programs for adolescents and adults (Alonso et al., 2016).

In North Rhine-Westphalia, the curricula for elementary school as well as the specifications for special educational support, including differentiated courses for learning and intellectual development, targeted courses and German sign language, as well as core curricula for lower secondary level, upper secondary level and further education colleges are specified. These guidelines are supplemented by additional and supporting information and materials for classroom implementation (https://www.schulentwicklung.nrw.de/lehrplaene/).

Among children between the ages of 6 and 15 years, error behavior is the most common cause of the traffic accidents cited. Young pedestrians most frequently make mistakes while crossing the road, either by not paying attention to vehicle traffic (53.2%) or by suddenly stepping out from behind visual barriers (31.4%). The most common causes of accidents among young cyclists are incorrect road use (17.9%) and errors while turning, reversing and starting (16.4%) (Federal Statistical Office, 2022).

In order to counteract children's misconduct in road traffic and reduce the number of traffic accidents, the North Rhine-Westphalia Conference of Education Ministers adopted a recommendation on mobility and road safety education in schools in 2012. This topic has been embedded in the curriculum under the area of mobility focusing on safe ways to school and road safety. The aim is for students to have acquired the necessary skills at the end of primary school to behave in accordance with standards and rules in road traffic by being able to apply the traffic rules when walking and cycling.

Young drivers are also a high-risk group in road traffic, as they are involved in accidents more frequently than other age groups. In 2022, 363 young people between the ages of 15 and 24 were killed in road accidents. The main reasons for this are a lack of driving experience (novice driver risk) on the one hand and frequently observed risk-taking behavior (youthfulness risk) on the other. Males in this age group in particular exhibit more risky driving behavior (Federal Statistical Office Destatis, 2023, GENESIS 46241-0007).

Therefore, the overarching educational task of schools serves to promote independent mobility and responsible participation in road traffic among students of all age groups. Road safety education is seen not only as a school responsibility, but also as a societal on, involving cooperation between the police, parents, traffic safety organizations, and other extracurricular parties.

In this context, physics experiments and practical applications can also play an important role in the context of traffic education in order to sensitize students to the physical principles of traffic and deepen their understanding thereof.

The curricular approach is based on the role of students as road users and develops a spiral curriculum for children, teenagers and young adults. Additionally, this curriculum may integrate physical concepts and principles of traffic alongside the conventional content of traffic education in order to promote a holistic understanding of the topic and prepare students for their role in traffic.

This concept can be successfully implemented only if qualified teachers are trained at universities. Therefore, the training of these teachers should include a sound understanding of the physical principles of traffic as well as pedagogical and psychological skills in the field of mobility and traffic education. This will enable them to support students effectively and guide them competently in both the physical and traffic education aspects of the curriculum.

2.2 The interaction between road traffic and physics

Physics plays an essential role in road traffic as it explains the fundamental principles and phenomena that influence the behavior of vehicles and road users. Some of the most important physical concepts in road traffic are:

- **Motion and speed:** Physical laws such as Newton's laws (laws of inertia) describe how vehicles move on the road, how they accelerate and brake and how their speed changes (https://www.leifiphysik.de).
- **Forces and force balance:** The forces acting on a vehicle - such as friction, inertial forces and air resistance - influence its movement and behavior on the road (https://www.tis-gdv.de).
- **Momentum and energy:** Physical principles such as conservation of momentum and conservation of energy explain the effects of collisions between vehicles or between vehicles and obstacles and how much energy is transferred (Schadschneider, 2004).
- **Reaction and braking distance:** The laws of physics also determine the braking distance and reaction time of vehicles, which is crucial for road safety (https://www.leifiphysik.de).
- **Optics and visibility:** Optical phenomena such as light refraction and reflection play a role in the design of traffic signs, road markings and lighting, which influence visibility and safety on the road (Bammel, 2007).

Therefore, an understanding of physics is of great importance for the safe and efficient design of educational lessons for safe road traffic methods as well as for road safety education and awareness.

2.3 The interaction between road traffic and traffic psychology

The interaction between road traffic and traffic psychology is of central importance for safety and efficiency in road traffic. Traffic

psychology examines the psychological processes and behaviors of road users that significantly influence accident risk and road safety.

An essential aspect of traffic psychology is the analysis of driving behavior. This includes, for example, the examination of reaction times, perception, neurobiological decision-making processes and the ability to act in stressful situations. These factors are crucial for recognizing potential dangers at an early stage and reacting appropriately.

Particular attention should be given to young drivers, who represent a high-risk group due to their lack of driving experience and frequent risk-taking behavior (Underwood, 2005, p. 129 ff.).

Young drivers, particularly those aged 16 to 24, are among the high-risk groups in road traffic. Studies show that they are significantly more likely to be involved in traffic accidents compared to older, more experienced drivers. The first 6 months after obtaining a driver's license are especially critical, as accident rates are at their highest during this period. Inexperienced drivers tend to engage in risky behaviors such as speeding, using mobile phones while driving, and being distracted by passengers during this time (McKnight and McKnight, 2003; Simons-Morton et al., 2017).

Another significant factor is the social influence of peers. Young drivers are often influenced by their passengers to engage in riskier driving behaviors, which further increases the likelihood of accidents. The presence of peers in the vehicle has a proven negative impact on driving behavior, as documented in numerous studies (Curry et al., 2017; Simons-Morton et al., 2017).

Moreover, many young drivers are not adequately prepared for complex traffic situations in the 1st months of driving independently. While supervised driving is generally safe, there is a high variability in the development of safe driving practices once drivers are on their own. This makes young drivers particularly vulnerable to accidents, especially when faced with challenging driving situations (Simons-Morton et al., 2017).

These findings highlight the need for targeted prevention measures, such as better preparation for complex driving scenarios and specialized programs to promote road safety among young drivers.

Traffic psychology offers important findings for the development and implementation of measures to reduce these accident risks. These include, for example, education and prevention programs, the promotion of defensive driving strategies and the integration of psychological findings into the design of traffic engineering measures. By closely linking psychological findings with traffic policy measures, road safety can be permanently improved.

2.4 Educational approaches to promoting road safety

From an educational perspective, road safety programs can be significantly enhanced by encouraging self-reflection among young drivers and by integrating such programs early into the school curriculum. Self-reflection plays a key role in developing safety-conscious behavior, as it helps young drivers critically assess their own actions and learn from them. Studies have shown that reflective processes can increase risk awareness and personal responsibility, which in turn can lead to a long-term reduction in accident risks (Zimmerman, 2002). Through targeted tasks and discussions that stimulate self-reflection, young drivers can become more aware of their attitudes and behaviors on the road and positively change them.

Moreover, the integration of road safety programs into the school curriculum offers a valuable opportunity to promote road safety awareness at an early stage. Schools provide an ideal platform to not only impart theoretical knowledge about road safety but also to develop practical skills that prepare young people for the challenges of driving. Research shows that early educational interventions, when consistently embedded in the school context, can lead to sustainable behavioral changes (Hattie, 2009). Such programs could cover topics such as risk behavior, safety strategies, and the psychological aspects of driving, thereby offering a comprehensive preparation for road traffic.

2.5 The importance of the authenticity of the topic

The education of future teachers aims at adapting the school curriculum to the needs and interests of the students. In this context, physics lessons have already been extensively studied, as explained above. Here in particular, it has been shown that the subject is often unpopular with students and is perceived as difficult (Merzyn, 2010, p. 9–12). This could be due to the fact that the lessons focus heavily on abstract mathematical aspects, as Merzyn explains. However, it turns out that students are much more interested in practical applications of physics than in purely theoretical aspects.

These findings underline the importance of experiments and practice-based approaches in teacher education. By integrating authentic tasks and a context-based research approach, teacher education students can learn how to make physics lessons clear and motivating. This not only promotes students' understanding, but also increases their motivation to actively participate in class (Redish, 2004).

The training of prospective teachers should therefore increasingly focus on providing them with the pedagogical skills and methodological know-how to make physics lessons practical and student-oriented. This includes the ability to plan and conduct experimental teaching units and to address the individual needs and interests of students. Such training can enable teacher education students to make physics lessons more engaging and accessible and thus improve the quality of teaching. The importance of authentic tasks is also widely documented. They can be used to support learning itself (Anderson, 1998) or to help students gain a better scientific understanding (Chang, 2005). Authentic tasks also increase students' motivation to actively participate in physics lessons (Kuhn, 2010).

Interventions, which in this case are intended to lead to more safety behavior among students, are generally only carried out if they are perceived as relevant and convincing for the target group.

As teachers, it is therefore crucial to design interventions that directly relate to the students' real environment and can

therefore serve as a basis for context-oriented teahcing. In physics lessons in particular, but also in general school lessons, more effective teaching strategies can be used to convince students of the importance and relevance of physics concepts.

The Aristotelian model offers a promising approach to teaching science. Since scientific reasoning is usually rationally motivated and logically structured, we as teachers can convince students by communicating these concepts clearly and precisely.

Weinert (2001) defines competencies as "the cognitive abilities and skills available to or learned by individuals in order to solve certain problems, as well as the associated motivational, volitional and social readiness and abilities to successfully and responsibly use these solutions in variable situations" (p. 27 f.). This understanding of competencies can be translated into a comprehensive teaching model that emphasizes the following aspects:

- **Knowledge (cognitive skills)**: The necessary theoretical understanding and information required to solve a problem.
- **Skills (practical abilities)**: The ability to practically apply the acquired knowledge and implement it in an action-oriented manner.
- **Values and attitudes (motivational, volitional and social dispositions)**: The attitudes and values that guide and influence actions.

This triad of "head, heart and hand" emphasizes that effective problem solving is characterized by cognitive processes as well as practical and emotional aspects. These elements are central to the debate around the concept of competence, as they reflect the holistic nature of competencies. People use their knowledge to purposefully shape actions which are in turn shaped by their values and attitudes—the latter acting as the "grammar" of behavior.

The implementation of this teaching model ensures that students not only acquire theoretical knowledge but are also able to apply this knowledge in practice and act responsibly through their values and attitudes.

At the University of Cologne, the "Traffic Physics" module was developed to specifically prepare prospective teachers for the challenges of traffic education. This module provides teacher education students with a solid understanding of the physical principles of traffic, the pedagogical and psychological backgrounds of traffic safety, and enables them to apply this knowledge in a clear and practical way in the classroom. The university course "Traffic Physics" aims to provide teacher education students of all school forms with practical experience in the field of context-oriented teaching. It offers a balanced composition of physical, pedagogical-didactic, and traffic psychological content, as well as practical experience in creating context-oriented tasks. Thus, the module makes an important contribution to the qualification of future teachers in the field of traffic education.

2.6 The curricular structure of the "Transport Physics" module

The "Traffic Physics" module is divided into five process phases based on the design thinking process, which outline the areas of problem understanding, problem solving and personal growth:

The first part is a classic lecture that provides an instructive introduction to various areas of traffic physics and mobility in childhood and adolescence (Limbourg et al., 2000). This instruction is carried out by the lecturers in specific sub-areas. The aim is for students to build up their theoretical knowledge of the causes of accidents and, by learning about the physical aspects of road traffic, to enable them to argue on a factual level.

The second part of the course takes on the characteristics of a seminar. Here, the students are presented with various accident black spots in the traffic space, which they are asked to examine on the basis of the aspects developed in the first part. The students are divided into small groups and document one accident black spot each. They receive support from road safety advisors from the police, or alternatively from members of the local traffic authority or members of the local public transport authority or other experts.

The groups then present their respective black spots and discuss why there are accident hazards at these locations and what measures can be taken to prevent accidents (Weber and Bresges, 2013a,b).

In the third part of the curriculum, students use the "Interview for Empathy" research approach to survey the problematic space of the school commute. They conduct interviews with various target groups in order to develop an in-depth understanding of the challenges and needs associated with walking to school. This method ensures that the best possible and repeatedly optimized innovative result is achieved (Grots and Pratschke, 2009). The students use these interviews to empathically put themselves in the position of those affected and to record the diverse aspects of the school commute.

First, potential danger spots in the immediate vicinity of the school, usually intersections, are analyzed using primarily qualitative observations. With this survey method, it must be considered that observations are only temporary and selective excerpts from reality and that subsequently only the traffic situation perceptible at that time can be recorded (Kochinka, 2010, p. 449–461). This means that the traffic situations observed during the interviews can only reflect a limited period of time and only certain aspects of the traffic space. For the transfer to general practice, this means that the findings and insights gained from the interviews should not be regarded as comprehensive or all-encompassing. Rather, they should be seen as a snapshot that makes it possible to identify specific challenges and needs in connection with walking to school.

In the fourth part of the course, the solutions developed are implemented in a prototyping process. Here, the ideas developed in the design thinking process are put into practice. Students are encouraged to transform their concepts into concrete models or designs in order to test their feasibility and effectiveness. This step gives students the opportunity to test their ideas in practice and identify potential weaknesses or opportunities for improvement at an early stage.

In the fifth part of the course, the iterative loop of evaluation follows, during which the students present their prototypes to the target group in order to obtain feedback. Here, the students have the opportunity to present their architectural models or designs of the road safety solutions to the real audience of the previously

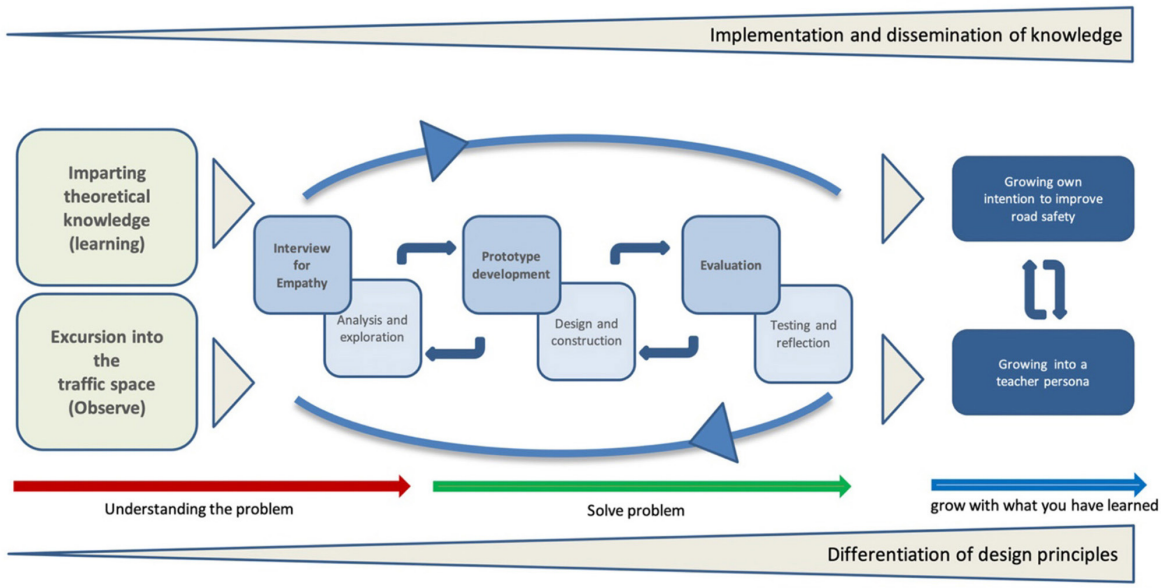

FIGURE 1
Contents and objectives of the "Transport Physics" module (source: own illustration).

interviewed target group, which represents the potential users. Through this presentation, students can receive valuable feedback that helps them to further improve and optimize their solutions. This iterative process allows students to adapt and refine their ideas based on feedback from the target audience to ultimately develop effective and practical road safety solutions.

Figure 1 shows an overview of the curricular module.

The knowledge acquired in the traffic physics module and the application of the design thinking process not only impact the professional know-how of the prospective teacher, but also shape their teaching personality in a variety of ways. Through a deeper understanding of traffic physics and the knowledge acquired in the field of road safety education, students develop an increased awareness of safety aspects in road traffic, which is reflected in their pedagogical actions.

In addition, the application of the design thinking process promotes the creativity, problem-solving and empathic skills of the prospective teacher. They learn to develop innovative solutions, analyze complex problems and respond to the needs of their students. This helps them to be flexible and resourceful as teachers and to be able to adapt lessons to the individual learning needs of their students.

Overall, the acquisition of knowledge in the traffic physics module and the application of the design thinking process means that the prospective teachers not only become more technically competent, but also develop their pedagogical skills and their personality as teachers. They become reflective and committed teachers who are able to motivate, support and inspire their students to develop safe and responsible behavior in road traffic (Reinmann, 2005, p. 52–69).

Therefore, the following research questions are addressed in this research paper:

Q1: How does the integration of the traffic physics module into teacher education influence the behavior and personal attitudes of prospective teachers with regard to road traffic?

Q2: Can criteria be detected that make the design thinking approach practicable in an end of module assessment in the "Traffic Physics" module?

Q3: Was it possible to develop grading criteria for the evaluation of end of module assessments in traffic space analysis in the module "Traffic Physics"?

3 Methodology

3.1 General framework conditions

The "Traffic Physics" module is offered annually in the summer semester at the Faculty of Mathematics and Natural Sciences at the University of Cologne, specifically at the Institute of Physics Education. It is aimed at teacher education students and offers both theory-based and practice-oriented training. The module can be completed with an end of module assessment. The number of participants is typically between 30 and 45.

The data collection for the present study spanned the years 2022 to 2024. In 2022, questions from Spicher and Hänsgen (2003)'s "Test for assessing traffic-relevant personality traits" (commonly abridged as TVP in German) were collected and compared using a pre- and post-test procedure at the beginning and end of the

TABLE 1 Overview pretest $N = 42$ (source: own presentation).

I am		
Answer	Quantity	Percentage
Female (F)	28	66.67%
Male (M)	13	30.95%
No answer	0	0.00%
Not finished or not shown	0	2.38%

TABLE 2 Overview posttest $N = 30$ (source: own presentation).

I am		
Answer	Quantity	Percentage
Female (F)	18	60.00%
Male (M)	9	30.00%
No answer	3	10.00%
Not finished or not shown	0	0.00%

module. The aim of this approach was to investigate changes in individual traffic behavior.

In 2023, a structured process was developed for the curriculum to determine the necessary criteria for an end of module assessment, which was based on existing and recurring criteria. Students checked the end of module assessments from the previous year to see whether these specified criteria could be found. This procedure was intended to check the feasibility of deriving grading criteria and their practicability for untrained prospective teachers and to identify potential difficulties in setting tasks or objectives.

In 2024, the grading criteria derived from these results were subjected to a final review by fully trained teachers.

The research methods are presented in the following chapters.

3.2 Analysis of the effects of the "Traffic Physics" module on individual norms, values and attitudes in road traffic

In order to evaluate the effectiveness of this module, various aspects of participants' individual norms, values and attitudes, as well as sanctions issued by road traffic monitoring authorities, were examined before and after completion of the module. This study aimed to gain insights into whether educational measures in the field of traffic physics can influence students' traffic behavior and attitudes. The results obtained indicate that the traffic physics education measures provided here had no significant influence on individual norms, values and attitudes in road traffic.

The participants in the pre-test were distributed as in Table 1.

The participants in the post-test were distributed as in Table 2.

The TVP is suitable for various areas of application, including the prediction of conspicuous traffic behavior. It is mainly used as a screening instrument. The instrument is based on the "Big Five" personality model and measures the dimensions of extraversion, emotional stability, conscientiousness, openness to experience, and agreeableness. In addition, the dimensions of trivialization and reactance, which were extracted for this study, are also measured. The modular structure allows the use of individual modules. A special feature of the test is the parallel recording of the main dimensions both across situations and traffic-specific, which results in a characteristic "double profile." This means that results can also be evaluated in the event of trivialization tendencies (Spicher and Hänsgen, 2003).

The test comprised two main categories. The first category (A1) recorded attitudes regarding behavior in road traffic. The second category (A2) examined whether there had already been sanctions imposed by the monitoring authorities in their personal history due to faulty behavior. The comparative analysis of categories A1 and A2 at the beginning and end of the curriculum aimed to determine whether the curriculum had a changing influence on traffic behavior.

The questions in category A1 examined the following characteristics of personal attitudes:

[I am careful when planning and acting]
[I feel safe even in difficult traffic situations]
[I like to react to prohibitions with a "now more than ever"]
[I like to try out what my car has to offer in terms of performance]
[I would like to remain free of obligations to friends]
[Successes make me take a higher risk]
[I strive for perfection in everything I do]
[I can call up a new playlist while driving if it doesn't take too long]
[I get nervous when I realize that a police car is driving behind me]
[I have driven a car before, even though I felt too tired to do so]
[The more difficult the traffic situation is, the more I enjoy it]
[At traffic lights I try to get away first]
[It has happened that I have driven faster than permitted]
[I only get in the car with someone if I know they are a conscientious driver]
[I am worried that something terrible might happen]
[If you drive carefully, the seatbelt is not necessary]
[Basically, two or three glasses of beer don't affect men when I'm driving]
[I regret many of my driving maneuvers afterwards]
[Even when I'm stressed, I stick to the traffic rules]
[My close friends can have a glass of beer, I'll get in anyway, because I trust them]
[I don't wear my seatbelt on short journeys]
[I am in favor of introducing harsher penalties for alcohol-related offenses]
[Other drivers often drive so badly that I get annoyed]
[As a passenger, I point out speeding to the driver]
[It excites me to drive faster than others]
[When the traffic light turns yellow, I hurry to go through]
[I've typed a text message while driving before because it was important]
[I never drive faster than usual, even under time pressure]
[If I see someone trying to drive who has been drinking, I call the police]

TABLE 3 Follow-up survey on transport use, j = 15 participants.

Mode of transport	Total users	Accidents (absolute)	Accident rate (%)
On foot	7	2	28.57
By bicycle	6	3	50.00
By car	5	1	20.00
By public transport	9	2	22.22
Other (skateboard)	1	1	100.00

[I am against the state introducing new methods of road safety checks]

[I have already tapped my forehead at another road user (a gesture that implies "I think you are crazy" in Germany)]

The questions in category A2 examined whether the participants had been sanctioned as active road users in the past year:

[...I have participated in road traffic as the driver of a vehicle]

[...I have had to pay fines/warnings]

[...I caused a traffic accident]

[...I have been reported for a traffic offense]

A follow-up survey was conducted 6 months after the "Traffic Physics" module with a subset of the participants (J = 16 participants) to determine the nature of their traffic participation and existing experiences with traffic accidents. The Number J = 16 represents the number of participants that were still available for an online-survey 6 months after the intervention. They represent 47% of the test group.

For the online-survey, the cloud service "SeaTable" (https://seatable.io/) was used, which is hosted on cloud servers in Germany and is compliant with the German Data Protection Regulation DSGVO.

Participants were asked: "What is your preferred mode of transportation in road traffic?" Which intentionally excludes answers for long-range and holiday travel. The survey yielded the results in Table 3.

The following stands out:

Bicycle use and accidents: Cyclists are among the most vulnerable road users, which is reflected in their high accident rate. In our group, the accident rate is 50%, which illustrates the increased risk of accidents for cyclists and confirms national trends. According to the Federal Statistical Office, many bicycle accidents occur due to collisions with motorized vehicles or obstacles (Statistisches Bundesamt, 2024). In Cologne, too, the accident figures for cyclists remain alarmingly high with 2,231 accidents and one fatality in 2024 (Statista, 2024), which is exactly reflected in the survey of the student subgroup.

Pedestrians: Pedestrians also feature in accident statistics as a vulnerable group, particularly due to collisions with vehicles in urban environments. In our group, around 28% of pedestrians have already experienced an accident, which confirms the higher accident rates for this group in urban areas and near schools (Statistisches Bundesamt, 2024). The number of accidents involving pedestrians also increased in Cologne in 2023: In a total of 646 accidents, 86 people were seriously injured and 14 people lost their lives (Polizeiliche Verkehrsunfallstatistik Police Cologne, 2023). These significant findings are also reflected in the results of this survey.

This national and regional data supports the findings of our student group and shows similar accident patterns for cyclists and pedestrians.

The results support the need for targeted traffic education measures to further improve the safety of these groups and raise awareness of the specific risks of different modes of transport.

3.3 Analysis of the feasibility of end of module assessments using the design thinking approach in the "Traffic Physics" module

To evaluate the feasibility of the design thinking approach in teaching and to develop an end of module assessment, criteria were defined to reflect the success of the students' research project. These criteria formed a continuum between "no research conducted" and "best possible research result achieved." The continuum was formed in the context of traffic space analysis on the following topics:

- Identification of relevant traffic problems.
- Creative idea generation for solutions.
- Application of design thinking methods for problem solving.
- Development and prototyping of innovative transport concepts.
- Implementation of user tests and iterative improvements.

These criteria were used to assess students' progress and success in applying the design thinking approach to their research project.

In a retrospective analysis anonymized end of module assessments were checked for the presence of the defined criteria. The end of module assessments were evaluated by students of a subsequent curriculum. The results obtained were intended to provide information on the feasibility and usefulness of applying the design thinking approach in teaching. A higher percentage of fulfilled criteria indicates a higher feasibility.

A total of $N = 34$ participants took part in the "traffic space analysis" survey. All participants were assessed using the same end of module assessment. This procedure contributes to the scientific robustness of the study. The consistency of the assessment materials ensures that the results are not influenced by varying levels of difficulty or differences in the content of the assessment. This strengthens the validity of the results and the reliability of the conclusions drawn from them.

The first category on the continuum of each subject area corresponds to the rating "no research conducted" and represents the lowest research effort. The following categories represent a gradual increase in research effort.

The following topics were mapped as a continuum and included in the assessment:

- Introduction to the topic.
- Description of the research design and research method.
- Description of the object of research (here: traffic space).
- Observation and analysis of traffic flow.
- Connection between road traffic and human behavior.
- Design of a prototype and its evaluation.
- Final conclusion and scientific assessment of the research process.

This process served as a transition to the next analysis procedure, namely the development of grading criteria. These grading criteria should enable future teachers to grade exam papers systematically and according to fixed criteria.

3.4 Analysis of the introduction of grading criteria for the traffic space analysis curriculum

Grading criteria define clear and measurable learning objectives that students should achieve at the end of a teaching module. The current teacher trainees should be enabled to assess their future students with the help of grading criteria in the "traffic space analysis" teaching module.

The introduction of grading criteria for the road safety analysis curriculum aims to establish clear learning objectives and outcomes to help trainee teachers develop a sound understanding of road safety assessment.

The main objective of this analysis is to investigate how grading criteria for the transportation analysis curriculum can be established and effectively implemented.

The grading criteria for the traffic space analysis curriculum included the following components:

- **Knowledge:** Understand basic concepts of road safety, including risk factors and protective factors in accident prevention.
- **Skills:** Develop analytical skills in brainstorming sessions to develop innovative solutions to identified traffic problems, evaluate traffic space constellations and identify danger spots.
- **Activities:** Creating prototypes, e.g., by modeling traffic space configurations or simulations.
- **Applications:** Ability to apply theoretical knowledge in practical scenarios, e.g., by carrying out traffic space design in the school environment.
- **Reflection:** Critical reflection on one's own research approach in the context of road traffic and the development of strategies to improve personal safety.

In this study, the qualitative coding manual of the grading criteria was analyzed using MAXQDA software. This approach aims to systematically structure and interpret the complexity and diversity of the data collected. The use of MAXQDA enabled a detailed and transparent preparation of the qualitative data through structured coding, which formed the basis for the analysis. Initially, various coding options were used in a pilot test to examine the fulfillment of the defined learning objectives and evaluation criteria (Table 4).

TABLE 4 List of codes (source: MAXQDA 24®).

Code system	
General introduction to the topic	**Human behavior**
General knowledge for introduction to the topic	Conscious dysfunctional behaviors (Alcohol, Speeding)
Correlations with one's own traffic world and personal experiences	Named correlations between misconduct and accident patterns
References to the curricular traffic education measures	Named approaches to solutions
Preview of the work and the expected research	Weighed advantages and disadvantages
Description of the research design and research method	**Design of a prototype**
Research design described in its approach	Prototype designed
Instruments used were named	Target group questioned for suitability and feasibility
Named advantages and disadvantages of the method	Prototype revised based on evaluation (iteration)
Research processes of own research described	Research results summarized and fully documented
Research subject traffic area	**Final conclusion**
Location of the research with sketches and photos	Research coherently summarized
Description of the location traffic-related	Research critically evaluated
Consequences of dysfunctional constellation	Outlook on necessary steps
Dysfunctional constellations meta-, meso-, and micro-level	Formalities and literature references
Observation of traffic flow	
Examples of functional dynamics	
Consequences or correlations with accident patterns	
Several concrete situational solutions	
Perspective of multiple users	

3.4.1 List of codes (code system)

The coding options were developed comprehensively to ensure a detailed and structured analysis of the grading criteria in the end of module assessment. This nuanced approach should make it possible to specifically examine the various aspects of road safety education and traffic space analysis in order to gain well-founded insights and continuously improve the effectiveness of the curriculum.

A key aspect of qualitative research is ensuring intercoder reliability, which measures the agreement between different coders and thus checks the reliability and validity of the coding. In this context, two research assistants were used to code the data

independently of each other. The intercoder reliability was then evaluated to analyze the consistency and agreement of the coding.

Again, the coders coded the same end of module assessment in order to attribute differences in coding to the raters themselves and their interpretation of the coding rules, rather than to differences in the assessment material, in addition to the reasons already mentioned above. This facilitates the analysis of intercoder reliability and the identification of areas where coding rules may need to be more clearly defined, which should be the particular focus of this research step.

In addition, this procedure enables the validation of the coding rules and methodology. By applying the same coding rules to the same material by different raters, the consistency and reliability of the coding rules can be checked. Differences in coding can be used to refine the rules and improve the training of raters.

However, unlike the previously employed students of the "Traffic Physics" module, the assistants had no prior knowledge of the module and received no technical instruction, which significantly influenced the evaluation of the results.

As a result of the pilot results, the codes were reduced to the main categories for better comprehensibility and these in turn were also simplified:

- Introduction
- Research method
- Traffic space analysis
- Behavioral analysis
- Prototype
- Conclusion

In addition, the thematic areas "traffic space" and "traffic flow" were merged into the coding area "traffic space analysis" to enable a more coherent and comprehensive analysis. Merging these two together facilitates the consideration of the dynamic interactions between the physical environment of the traffic space and the movement patterns of road users. By integrating both aspects into a single coding area, a holistic perspective is promoted that considers both static and dynamic elements, allowing for a deeper understanding of road safety and efficiency. This facilitates the coding process by minimizing the risk of misunderstandings.

4 Results

4.1 Results of the quantitative methods

4.1.1 Results of the analysis of the effects of the "Traffic Physics" module on individual norms, values and attitudes in road traffic

The following statistical analyses were carried out to compare scale A1 (attitudes and behavior) between the pretest and posttest:

A *t*-test for independent samples was used after the conditions of normal distribution and the absence of outliers were ensured. There was also homogeneity of variance.

The test statistic resulted in $t_{(62)} = -1.220$, $p = 0.227$.

These results show that there is no significant difference in the A1 scale between the pretest and posttest groups (Table 5).

Due to the non-significance of the difference, the effect size was not interpreted.

Table 6's statistical analyses were carried out to compare scale A2 (sanctions by supervisory authorities) between the pre-test and post-test:

Originally, a *t*-test for independent samples was planned. However, it was found that the normal distribution assumption was not met, based on the Kolmogorov-Smirnov test with $p < 0.001$ for both the pretest and posttest groups.

A Mann-Whitney U test was therefore carried out. This resulted in a significant deviation from an equal distribution, which means that no differences in the medians can be interpreted. The Kolmogorov-Smirnov Z-test resulted in $p = 0.004$.

The test statistic for the Mann-Whitney U test was U = 411,000, Z = −1.359, $p = 0.174$.

These results show that there is no significant difference between the pretest group and the posttest group in the A2 scale.

Q1: How does the integration of the traffic physics module into teacher education influence the behavior and personal attitudes of prospective teachers with regard to road traffic?
Answer: It can be stated that the integration of the traffic physics module into teacher education does not significantly influence either the behavior or the personal attitudes of prospective teachers with regard to road traffic.

4.1.2 Results of the analysis of the feasibility of end of module assessments using the design thinking approach in the "Traffic Physics" module

The results of the retrospective evaluation of the completed end of module assessment in terms of the performances achieved were categorized within the established criteria continua and yielded the following results:

We will now evaluate the content of the seven chapters of the student work.

Chapter: *Introduction to the topic*

The examination papers in the "Transport Physics" module showed clear strengths in the general introduction to the topic, which underlines the students' ability to anchor fundamental concepts and important connections in their papers. Of particular note is that 90.48% of raters recognized general introductory knowledge of the topic, such as causes of accidents and relevant statistics, in the students' examination papers. This high rate shows that students were able to lay a solid foundation for their work by presenting essential information in a clear and understandable way.

In addition, 57.14% of raters identified connections between the topic of road safety and the students' own transportation world, including their personal experience as well as social and political events. This shows that a significant proportion of students were able to put theoretical knowledge into a real context and work out the relevance of the topic to their personal experience and the

TABLE 5 Test statistics for the survey of behavioral change (source: SPSS®).

Group statistics				
	Time point: pre- or post-test	N	Mean value	Std. deviation
A1: My behavior in traffic	Pre-test	30	2.0118	0.26158
	Post-test	34	0.20949	0.28031
Group statistics				
	Time point: pre- or post-test	Standard error of the mean		
A1: My behavior in traffic	Pre-test	0.04776		
	Post-test	0.04807		
Test with independent samples				
		Levene's test for equality of variances		*t*-test for equality of means
		F	Sig.	T
A1: My behavior in traffic	Variances are equal	0.011	0.918	−1.220
	Variances are not equal			−1.226
Test with independent samples				
		t-test for Equality of Means		
			Significance	
		df	One-tailed p	Two-tailed p
A1: My behavior in traffic	Variances are equal	62	0.114	0.227
	Variances are not equal	61,792	0.113	0.225

TABLE 6 Test statistics for the survey of road traffic sanctions (source: SPSS®).

Tests for normal distribution				
		Shapiro-wilk		
	Time point: pre- or post-test	Statistic	df	Significance
A2: My type of active participation and previous sanctions in traffic	Pre-test	0.863	30	0.001
	Post-test	0.871	34	<0.001
Test statistics[a]		**z-Score: A2: My type of active participation and previous sanctions in traffic**		
Extreme differences	Absolute	0.439		
	Positive	0.439		
	Negative	−0.094		
Kolmogorov-Smirnov-Z		1.753		
Asymp. Sig. (2-tailed)		0.004		
Test statistics[a]		**z-Score: A2: My type of active participation and previous sanctions in traffic**		
Mann-Whitney U Test		411.000		
Wilcoxon W		1006.000		
Z		−1.359		
Asymp. Sig. (2-tailed)		0.174		

[a]Grouping Variable: Time Point: Pre- or Post-test.

social environment. The integration of curricular measures was also rated particularly positively. 66.67% of the raters found references to traffic education measures in the school context in their work. This link shows that the students have developed an understanding of how the theoretical concepts of traffic physics can be embedded in the practice of traffic education, which is of great importance for their future role as teachers. Furthermore, 71.43% of raters saw the papers as a preview of the work and research to come. This shows that the majority of students were able to design a clear structure and logical flow for their academic work, which provides helpful guidance for readers and significantly enhances the quality of the papers.

Overall, these results underline the students' strength in the general introduction and contextualization of their topics, which provides a solid foundation for their academic work and demonstrates their ability to bring theoretical knowledge into practical contexts.

Chapter: ***Description of the research design and method***

The examination papers in the Transport Physics module showed notable strengths in various aspects of the description of the research design and the research methods used. A particularly positive aspect was the naming of the instruments used, such as interviews and written surveys, which were described as clear and precise by 90.48% of raters. This high rate shows that the students were able to clearly identify and communicate their methodological tools, which is of central importance for the traceability and replicability of their research.

In addition, 57.14% of raters rated the presentation of research procedures as detailed and comprehensible. This underlines the students' ability to clearly structure and document their methodological steps, which is essential for understanding and evaluating the scientific work. A clear presentation of the research procedures makes it possible to follow the entire research process transparently and logically.

Although 38.10% of raters rated the description of the research design as complete, this shows that a significant number of students were able to present their research design comprehensively. These students have shown that they are able to formulate their methodological approach clearly and completely, which forms the basis for a solid scientific paper.

Another important aspect is reflecting on the advantages and disadvantages of the chosen methods. Although this was only found in the work of 14.29% of raters, this shows that some students incorporated a high degree of critical reflection into their methodological discussion. This ability to reflect is crucial for the further development and improvement of scientific methods and demonstrates a deeper understanding of the complexity of the research methods used.

Overall, students demonstrate a strong ability to clearly present their methodological approaches, particularly in terms of naming instruments and structuring research procedures. These strengths lay a solid foundation for future academic work and show that students are well equipped to successfully plan and conduct challenging research projects.

Chapter: ***Research subject traffic area***

Analysis of the examination papers in the "Transportation Physics" module shows that the majority of students were able to describe the research site in detail and vividly. A total of 85.71% of raters rated the presentation of the research site as detailed and visually supported by sketches and photos. This visual support is particularly valuable as it gives readers a clear picture of the research site and makes it easier to understand the specific transportation-related challenges of the site. The ability to represent the research site visually, as well as textually, demonstrates that students have developed a comprehensive understanding of the importance of spatial context in transportation spatial analysis. Such detailed descriptions are crucial for the comprehensibility of the research and make it possible to interpret the research results in the context of the specific local conditions.

The presentation of traffic-related problems at the investigated location was also rated positively. Here too, 85.71% of the raters stated that the examination papers contained detailed descriptions of the traffic-related problems. This shows that the students were able to clearly identify and present the specific challenges and risks that exist at the respective locations. A precise description of the problems is essential to emphasize the relevance of the research and provide the basis for the development of solutions. It is encouraging to see that such a high proportion of students have successfully completed this task.

Another important aspect that was considered in the examination papers is the presentation of the consequences of dysfunctional traffic-related constellations. 66.67% of raters saw a clear presentation of these consequences. This shows that the majority of students not only identified the problems, but also analyzed the potential impacts and risks that could result from these transport-related challenges. The ability to present the consequences of dysfunctional constellations is a sign that students have developed a deep understanding of the dynamics and potential dangers in specific traffic space scenarios. Such an analysis is essential in order to propose well-founded and practical solutions. Finally, 57.14% of raters noted that the papers considered different levels (meta-, meso-, and micro-level). This means that slightly more than half of the students were able to conduct their analysis at different levels of abstraction in order to develop a more comprehensive understanding of transportation-related problems. Considering the meta-level allows one to analyze the larger societal and structural framework, while the meso-level focuses on specific institutions or groups and the micro-level focuses on individual behavior. An analysis that includes all of these levels enables a holistic view of the problem and helps to develop solutions that take both systemic and individual aspects into account. However, the rate of 57.14% also shows that almost half of the papers did not fully implement this multidimensional approach, which indicates a possible weakness in the depth of the analysis.

In summary, the evaluation shows that most students were able to present the research site in a detailed and visually appealing way and clearly identify the specific transportation-related problems. The analysis of the consequences of dysfunctional constellations and the consideration of different levels of analysis were also present in the majority of the papers, although there is still room for improvement here. Overall, the results suggest that the students have developed a solid understanding of the challenges and dynamics of the research site, while at the same time they could be encouraged to conduct an even more comprehensive and multidimensional analysis.

Chapter: ***Observation of traffic flow***

The analysis of the examination papers in the Traffic Physics module highlights several strengths, particularly in relation to the identification and representation of functional and dysfunctional dynamics in road traffic. A total of 76.19% of raters rated the naming of such dynamics, such as regulated traffic flow or excessive speed, as appropriate. This high rate shows that the majority of students were able to recognize and accurately describe critical aspects of traffic flow. The ability to distinguish functional dynamics that contribute to traffic safety from dysfunctional dynamics that increase potential hazards is crucial for a sound analysis of traffic-related problems and for the development of effective solutions. Another strong element in the audit work was the identification of correlations between traffic behavior and accident patterns. 66.67% of raters recognized that clear links were drawn in the papers between specific behaviors and the resulting accident patterns. This ability to recognize and present causal relationships is of central importance for the development of preventive measures and the improvement of road safety. It shows that the students have developed a deep understanding of the causes of accidents and are able to place their findings in a wider safety-relevant context. The development of concrete, situation-related solutions in the examination papers is also particularly noteworthy. 71.43% of raters found several practical and contextualized solutions in the papers that were aligned with the identified traffic-related problems. This indicates that students can not only diagnose problems but also develop effective and implementable solutions. The ability to propose practice-oriented solutions is an essential goal in the training of future teachers, especially in the field of transportation physics, where theoretical knowledge must be combined with practical application. Another notable strength of the exam papers was the inclusion of the perspectives of multiple user groups, such as residents, cyclists, pedestrians and motorists. 95.24% of raters noted that these different perspectives were included in the analysis. This comprehensive consideration of different road users is critical to developing holistic solutions that meet the needs and safety requirements of all stakeholders. The ability to integrate different perspectives demonstrates a high level of reflection and an understanding that transportation problems can only be solved effectively if the interests of all user groups are considered.

In summary, the results of the examination papers in the "Traffic Physics" module reflect a strong performance by students, particularly in the identification and analysis of traffic flow dynamics, linking traffic behavior to accident patterns, developing situational solutions and incorporating different user perspectives. These strengths underline the students' ability to recognize complex traffic-related problems and to develop practical, comprehensive solutions.

Chapter: ***Human behavior***

Examination papers in the Traffic Physics module show remarkable strengths in analyzing the relationship between human behavior and road traffic and in developing solutions to improve traffic safety. While only 14.29% of raters found no connection between road traffic and human behavior in the papers, this indicates that the vast majority of students were able to make this critical connection. This ability is crucial, as understanding how human behavior affects road traffic is the basis for developing effective prevention measures.

Particularly positive is the fact that 28.57% of raters identified examples of functional and dysfunctional behaviors on the road. This shows that a significant proportion of students were able to recognize specific patterns of behavior that either contribute to safety or increase risk. This distinction is critical to developing targeted interventions to promote safety-enhancing behaviors and reduce risky behaviors. More significantly, 47.62% of raters saw clear links between human error and accident patterns in the papers. This highlights the students' ability to analyze the causes of traffic accidents at a behavioral level and understand the underlying mechanisms. Such an understanding is essential in order to design preventative measures aimed at correcting misbehavior and thus minimizing the risk of accidents. However, the greatest strength of the audit work lies in the development and evaluation of solutions. 66.67% of the raters rated the approaches developed to solve personal misconduct in road traffic as useful. These solutions demonstrate practice-oriented thinking and the ability to translate theoretical knowledge into concrete recommendations for action. This is a central goal in the training of future teachers, who must be able not only to teach their students, but also to actively contribute to a safer traffic environment.

Finally, 76.19% of raters noted that the examination papers weighed the pros and cons of the proposed solutions by including the perspectives of multiple user groups. This differentiated view shows that students are able to critically scrutinize solutions, taking into account the diverse interests and needs of different road users. The inclusion of different perspectives is crucial for the development of measures that are both practicable and fair.

In summary, the results of the examination papers illustrate that students have developed a solid ability to analyze and solve problems in the field of human behavior in road traffic. Particularly noteworthy is their ability to develop meaningful solutions and to evaluate them critically, taking into account different perspectives. These strengths form an excellent basis for further training and practical application in professional life.

Chapter: ***Design of a prototype***

The examination papers in the Transport Physics module show clear strengths in the development and evaluation of prototypes, highlighting students' ability to apply theoretical concepts in practice. At 90.48%, most raters recognized a developed prototype in the papers, whether architectural or digital. This high rate illustrates that students were successfully able to translate their theoretical knowledge into concrete, tangible solutions. The ability to develop a prototype demonstrates not only technical ability, but also creativity and a deep understanding of the requirements placed on a practical solution. This is a key skill that is invaluable in modern education and engineering.

The target group evaluation was also rated as detailed by 85.71% of raters. This shows that the students not only developed prototypes, but also carefully evaluated them in terms of their suitability, feasibility, and financial viability. Such a comprehensive evaluation is crucial to ensure that the solutions developed work in practice and meet the needs of users. The

ability to conduct a thorough target group evaluation reflects a deep understanding of the requirements and constraints that need to be considered when implementing solutions in the real world.

Another positive aspect is that 47.62% of raters recognized a need to rework the prototype based on the results of the evaluation. This iterative process of improvement shows that students are not only able to accept constructive criticism, but also actively work to optimize their solutions. The ability to revise and adapt prototypes is a sign of flexibility and a solution-oriented approach, which is crucial in research and development.

Finally, the documentation of research results for the development and evaluation of the prototype was rated as complete by 76.19% of raters. Thorough documentation is essential to ensure the traceability and reproducibility of research. The students showed here that they are able to document their work systematically and in detail, which is an important basis for knowledge transfer and further research. In summary, the examination papers in the "Transport Physics" module demonstrate the students' strong competence in prototype development and evaluation. Particularly noteworthy are their abilities to develop practical solutions, evaluate them thoroughly and revise them if necessary. The comprehensive documentation of their work rounds off the picture of a methodologically sound and practice-oriented approach that prepares the students excellently for future challenges in their professional environment.

Chapter: ***Final conclusion***

The examination papers in the "Transport Physics" module show significant strengths in the development of coherent conclusions and critical reflection on the research carried out.

One notable aspect is that all raters unanimously found that a coherent conclusion was drawn in the papers. This underlines that the students were able to summarize their findings clearly and concisely and bring the main findings of their research to a consistent and logical conclusion. The ability to draw a coherent conclusion is a sign that students have not only understood the individual aspects of their research, but are also able to integrate them into a coherent overall picture. This competence is of central importance for academic work and shows that students have a high level of analytical skills. In addition, 66.67% of raters rated critical appraisal of research as present. Critical appraisal is an essential component of academic work, as it enables students to reflect on their own research findings in the context of existing literature, recognize the limitations of their own work and identify potential areas for improvement. The fact that the majority of students have undertaken such a reflection in their work demonstrates their ability to be self-critical and to engage in a well-founded discussion of the strengths and weaknesses of their research. This is an important step in academic training, as it forms the basis for continuous learning and the improvement of one's own academic practice. Another positive aspect is that 80.95% of raters found an outlook on necessary steps in the papers. An outlook is crucial to clarify the importance of the research results for future work and practical application. The ability to identify potential next steps and place them in the context of their own research shows that students can not only analyze retrospectively, but also think ahead. This foresight is essential to ensure the practical benefits and further development of research.

Finally, 71.43% of raters rated the adherence to formalities and references as sufficient. This shows that the majority of students were able to fulfill the formal requirements of a scientific paper, including correct citation and adherence to style guidelines. Adherence to these formalities is not only a matter of diligence, but also an expression of respect for the scientific community, as it ensures the traceability and integrity of the work.

In summary, the examination papers in the "Transport Physics" module demonstrate students' strong skills in drawing coherent conclusions, critically reflecting on their research and formulating a forward-looking outlook. These strengths show that the students are well prepared for the challenges of scientific work and are able to present their findings in a structured and reflective manner. The analysis of the 34 assessed final module examinations shows that clear research efforts were evident in the vast majority of the papers. Only in 13.60% of the papers were no research efforts identified, indicating that the vast majority of students were actively immersed in academic debate. Research efforts in the various subject areas and sub-categories varied from 14.29% to an impressive 95.24%, highlighting the range and engagement of students in different areas.

Of particular note is that at least 47.62% of the expected knowledge was achieved in 19 out of 20 subcategories, with as much as 71.43% or more of the expected knowledge being covered in 12 of these subcategories. These results show that a significant proportion of students have a solid understanding and knowledge base in the respective subject areas.

However, it is important to note that the assessments were conducted by untrained students, which could pose some potential risks. These may be as follows:

- **Lack of objectivity:** Inexperienced students may find it difficult to evaluate objectively and fairly as they lack experience and expertise.
- **Lack of subject knowledge:** Inexperienced students may find it difficult to adequately assess the quality and depth of the work, especially when it comes to specific subject content.
- **Lack of sensitivity to grading criteria:** Inexperienced students may have difficulty applying the relevant grading criteria appropriately, which can lead to inconsistent or inaccurate assessments.
- **Potential misinterpretation:** Inexperienced students may misinterpret or misjudge certain aspects of the work, which can lead to inaccurate results.
- **Biased assessments:** Inexperienced students may give subjective assessments based on their own prejudices or opinions that are not based on the objective grading criteria.

Q2: Can criteria be detected that make the design thinking approach practicable in an end of module assessment in the "Traffic Physics" module?
Answer: It can be stated that criteria could be detected that allow the presentation of the design thinking approach for the structured analysis of a traffic space and its solution finding in an end of module assessment.

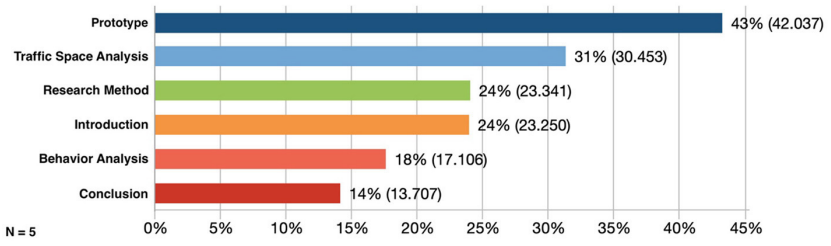

FIGURE 2
Coverage of the codes of the second rating (source: MAXQDA®).

4.2 Results of the qualitative methods

The evaluation of the qualitative method of the grading criteria using MAXQDA resulted in intercoder reliability agreements of between 7% and 22% in the main categories. These low agreement values raise questions regarding the reliability and consistency of the coding. It should be noted that two research assistants, who were unfamiliar with the module and had not previously received any specialist instruction, carried out the coding. These conditions can be regarded as significant factors influencing the low agreement rates.

The two research assistants had previously been given the coding manual[2] with the coding rules and explanations but admitted that they had not looked at it beforehand. They had tried to understand the explanations during the coding process, which was not sufficient. The author was not asked any substantive questions during the coding process.

The lack of knowledge of the module, the lack of professional instruction and the coders' failure to ask questions probably led to different interpretations of the data and a varying application of the codes. This is reflected in the low intercoder reliability, which indicates that the coding of the assistants was not sufficiently consistent to ensure reliable results. The variance in agreement rates suggests that more training and familiarization of coders is required to achieve greater consistency and accuracy in coding.

To improve the reliability of the qualitative data analysis, a further data collection was conducted in an iterative loop in which $N = 5$ new raters performed the coding according to simplified main categories. The matches in the categories were as in Figure 2.

The analysis of the results from Chapter 4.1.2 of the coding development process compared with the information from Figure 2 of the real coding process showed that certain areas performed particularly well. In prototype development, 90.48% of evaluators identified a developed prototype in the development process, and 85.71% rated the detailed survey on the suitability and feasibility of the prototype as very good. These results were confirmed by the high coverage of the corresponding codes in the real coding process indicating thorough and detailed documentation of the prototype development.

In the general introduction and research design, 90.48% of the evaluators of the development process noted that the tools used were clearly identified and recognized introductory knowledge. This positive assessment is also reflected in the actual coding process where good coverage of the codes indicates a comprehensive treatment of the topic and a detailed description of the methods.

Traffic space analysis and traffic flow were also rated positively, with 85.71% of the evaluators in the development process finding detailed descriptions of traffic-related problems and 76.19% rating the naming of functional and dysfunctional dynamics as appropriate. Figure 2 shows high coverage in these areas, confirming thorough investigation and analysis during the actual coding process.

Finally, the conclusions and the critical evaluation were consistently rated positively. 100% of the evaluators found coherent conclusions, and 80.95% gave an outlook on necessary steps in the development process. These positive ratings were supported by the good coverage of the conclusion codes in the actual coding process.

In summary, the comparison demonstrates that the areas of prototype development, general introduction, research design as well as traffic space analysis and traffic flow were particularly positively emphasized in both rounds. These areas showed consistently high quality and thorough processing, which is evident both in the evaluators' ratings and in the coverage of the codes in Figure 2.

Overall, these results showed improved intercoder reliability in the individual categories, although this continued to vary in other sub-areas. The coding results suggest that the conclusion in particular was only addressed in a rudimentary manner. This indicates that the raters were under considerable time pressure at the end of the coding period. The graduates of the "Traffic Physics" module had a limited time of 90 min to code 78 pages. In comparison, the two research assistants in the first round needed an average of 2.5 h for the same task without any time limit.

The discrepancy in processing time suggests that the time pressure on module graduates led to less thorough coding, especially in the later sections such as the conclusion. This could explain why the conclusion was only treated superficially. In contrast, the research assistants had the opportunity to code at their own pace, which led to a more detailed and comprehensive analysis.

2 Coding manual see Appendix 1.

These observations underline the importance of sufficient time resources for thorough and accurate coding in qualitative studies. Too little time can significantly affect the quality of coding and lead to incomplete or erroneous results. It is therefore essential to set a realistic time frame for such tasks in order to ensure the validity and reliability of the research results.

4.3 Conclusion

The iterative review and adjustment of the codes has led to an improvement in the clarity and applicability of the main categories. The results of further data collection show progress, but also the need for further refinements in the process for raters to ensure greater consistency and reliability in the application of the codes. The time pressure at the end of the coding period may have affected the accuracy and completeness of the coding, which should be considered in future coding processes.

Q3: Was it possible to develop grading criteria for the evaluation of end of module assessments in traffic space analysis in the module "Traffic Physics"?
Answer: It can be stated that basic grading criteria could be developed. These can be refined through further research.

4.4 Summary of all research results and inclusive interpretation

The present study showed that the integration of the module "Traffic Physics" into teacher training does not have a significant influence on the behavior or personal attitudes of prospective teachers with regard to road traffic. This result is in line with previous studies showing that traffic safety-oriented educational programs often increase participants' knowledge, but do not necessarily lead to a change in behavior (Faus et al., 2023).

The hypothesis that criteria for the design thinking approach for the structured analysis of a traffic area can be developed and successfully applied in module examinations was supported by the present results. The design thinking approach proved to be suitable for supporting systematic problem analysis and innovative solution finding and for providing a valid examination methodology. Previous studies have already shown that the design thinking approach can be used successfully in teacher training (Weber and Bresges, 2013a,b).

In addition, a basic horizon of expectations for module completions could be defined as part of the traffic area analysis, which can be further specified and optimized through future research. Such a horizon of expectations contributes to objectivity and consistency in the assessment and supports pedagogical quality assurance in the teaching context (Hattie, 2009).

In summary, it can be stated that the "Traffic Physics" module provides relevant methodological and organizational structures for improving teacher training in the field of road safety, even if changes in the participants' behavior cannot be directly demonstrated.

5 Discussion

5.1 Discussion of the project as a whole

The application of the "Traffic Physics" curriculum for the training of teacher education students, including the design thinking approach, can be structured by the triad as formulated by the KMK Expert Commission (Baumert, 1995, p. 70 ff.): in-depth general education, scientific propaedeutics, and study skills. These dimensions must be interpreted in a domain-specific manner in order to achieve the objectives of the "Traffic Physics" curriculum.

5.1.1 In-depth general education

The advanced general education in physics as part of the "Traffic Physics" curriculum goes beyond the requirements of basic scientific education and includes the following aspects:

- **Increasing the level of reflection**: Through the design thinking approach, students learn to methodically analyze complex traffic problems and develop innovative solutions (Schecker et al., 2004, p. 5 ff.). The process begins with the **empathy phase,** in which the students develop a deep understanding of the needs and challenges of road users through interviews and observations, particularly in relation to school commuting.
- **Specialization and transcendence**: In the **definition phase,** students specialize in making the knowledge they have gained more precise and identifying specific problems (Schecker et al., 2004, p. 5 ff.). Through the subsequent **ideation, prototyping, and testing phases,** they learn to apply physical principles in practice and develop innovative solutions that go beyond pure theory and can be used across disciplines, such as the development of safe routes to school.
- **Expansion and transfer possibilities of in-depth general education:** In addition to increasing the degree of reflection and subject specialization, the "Transport Physics" curriculum offers students the opportunity to transfer the physical concepts they have learned to other, non-transport-related areas. This ability to transfer knowledge could, for example, include the application of physical principles to environmental topics or technical problems. The ability to apply knowledge flexibly and in different contexts is a central aspect of in-depth education and underlines the comprehensive effectiveness of the curriculum. In his work, Hattie (2009) emphasizes the importance of deep learning and knowledge transfer, which plays into the argument for in-depth general education and interdisciplinarity. In addition, the curriculum strengthens interdisciplinarity by combining physics content with pedagogical and road safety aspects. This interdisciplinary focus broadens students' horizons and prepares them to solve complex problems in a broad context - an essential skill for teachers in the 21st century. Bransford et al. (2000) discuss in their work how learners can apply and transfer knowledge in new contexts, which directly addresses the idea of knowledge and skills transfer and underlines the importance of this approach in the transport physics curriculum.

5.1.2 Science propaedeutics

Science propaedeutics as part of the "Traffic Physics" curriculum means:

- **Introduction to scientific work**: Students are introduced to scientific methods and techniques that they can try out in educational contexts (Schecker et al., 2004, p. 5 ff.). The design thinking process, especially the **prototyping phase**, promotes the ability to experimentally apply and document their research results.
- **Fault tolerance and reflection**: The iterative nature of the design thinking approach, especially during the **testing phase,** enables students to view mistakes as learning opportunities and to continuously reflect on and improve their approaches. This ability to reflect is crucial for the development of a scientific attitude and the understanding of physical concepts (Schecker et al., 2004, p. 5 ff.).
- **Promotion of research skills and critical thinking through scientific propaedeutics:** The "Transport Physics" curriculum goes beyond the mere application of scientific methods by encouraging students to develop independent research skills. The design thinking approach encourages students to formulate and systematically investigate their own research questions. This ability to independently initiate and carry out scientific projects is a crucial step toward independent and professional teacher training. At the same time, the iterative nature of the design thinking approach not only promotes fault tolerance, but also critical thinking. Students learn to critically question existing approaches and theories and to develop alternative solutions, which enables a well-founded scientific attitude and a deeper examination of physical concepts. In this context, Wiggins and McTighe (2005) provide a valuable foundation as their backward-looking design structures the process of developing research skills while encouraging students to think critically.

5.1.3 Ability to study

Ensuring the ability to study of teacher education students within the framework of the "Transport Physics" curriculum includes:

- **Basic skills**: Students develop basic skills such as clearly stating facts, understanding texts and modeling facts in mathematical contexts (Schecker et al., 2004, p. 5 ff.). These skills are constitutive for physical theory formation and are promoted by the practice-oriented design thinking approach, especially during the **prototyping and testing phases.**
- **Key qualifications**: Due to the experimental and project-based nature of the curriculum, students develop key qualifications such as decision-making skills, perseverance, communication and cooperation skills (Schecker et al., 2004, p. 5 ff.)**.** These are reinforced through practical work on real road safety problems, which are solved using the design thinking approach.
- **Sustainability and long-term skills development to ensure the ability to study:** Another key aspect of the "Transport Physics" curriculum is the sustainability of the skills taught. The basic skills and key qualifications developed as part of the curriculum are not only relevant during the course of study, but are also of great importance in the professional practice of teachers in the long term. This sustainability is strengthened by the practical and project-based structure of the curriculum, which helps students to continuously apply and further develop the skills they have learned. In this context, the concept of the "reflective practitioner" by Schön (1983) can be used, which emphasizes how important it is for professionals to continuously reflect on their actions and learn from their practical experience. The Transportation Physics curriculum fosters this reflective ability by encouraging students to critically question their own actions and decisions and learn from them, which lays the foundation for lifelong learning. In addition, the curriculum prepares students for lifelong learning by providing them with the tools to continue their education after graduation and to tackle new challenges in education and transportation. This focus on long-term skills development, which is strongly based on Schön (1983)'s concept of the reflective practitioner, makes the "Transport Physics" curriculum a modern and future-oriented educational approach that prepares students for the complex demands of the teaching profession.

These phases of the design thinking approach make the "Traffic Physics" curriculum practical and interactive, which takes the training of teacher education students to a new level. It allows them to apply theoretical knowledge in practical contexts and effectively prepares them for their future tasks as teachers.

5.2 Discussion of the scientific quality criteria

Compliance with scientific quality criteria is of central importance for the methodological reflection of scientific studies. These criteria serve to ensure the safety, transparency, reliability and validity of scientific findings (Häder, 2010, p. 108). In the context of this research work, a nuanced consideration of quality criteria is necessary, which focuses on two essential aspects:

- **Quality criteria of quantitative research**: Quantitative research methods are characterized by the systematic collection and evaluation of numerical data. The quality of such research approaches is assessed on the basis of various criteria such as validity, reliability and objectivity. Validity refers to the accuracy and appropriateness of the constructs measured, while reliability refers to the consistency and reliability of the measurements. Objectivity refers to the extent to which the results are independent of the individual assessments of the researchers (Häder, 2010, p. 108).
- **Quality criteria for qualitative research**: In qualitative research, the focus is on interpretation and understanding processes. The quality criteria for qualitative studies include reproducibility (the possibility of reproducing the research steps), transferability (the generalizability of the results to

other contexts), consistency (the internal coherence of the results) and reflexivity (the researcher's critical examination of his or her role and influence on the study) (Häder, 2010, p. 108).

Taking these quality criteria into account helps to ensure the methodological quality of the research work and to make its results reliable and comprehensible. Care should be taken to ensure that the criteria are adapted to the specific requirements of quantitative or qualitative research.

5.2.1 Quality criteria for quantitative research

The aim of measurements in quantitative research is to collect data that is as accurate and error-free as possible. In practice, however, this ideal is rarely fully achieved. The "classical test theory" provides simple definitions of quality criteria for measurement. According to this, measurements should be objective, reliable and valid as well as economical, comparable and useful in practical implementation. Objectivity and reliability are considered the minimum requirements for a measurement instrument (Häder, 2010, p. 108), while the main objective is to construct instruments that are as valid as possible.

When evaluating a teaching module, individual perspectives are reflected in subjective judgments, perceptions, attitudes, and views of the respondents, which can affect validity (Schubarth, 2006, p. 282). To address these challenges, the instruments used must be carefully developed and tested to ensure that they measure the intended constructs accurately and reliably.

The **result of the evaluation of the "Traffic Physics" curriculum** showed no significant changes between the pretest and the posttest. If no significant results were achieved, this may be due to various factors:

- **Sample size:** The size of the sample plays a crucial role in the statistical analysis of data. In the present study, the sample size may not have been large enough to detect small but still relevant differences between the groups. A small sample increases the risk of missing true differences—a problem known as Type II error. With a larger sample, the statistical power, i.e., the ability of a test to detect actually existing effects as significant, increases. A larger sample size might have made it possible to identify subtle effects that remained hidden in the present analysis. This emphasizes the importance of careful sample size planning, especially in studies investigating differences between groups.
- **Sensitivity of the test:** Another factor that could influence the results is the sensitivity of the statistical test used. Statistical tests differ in their ability to identify differences between groups as significant. It is possible that the test used in this study was not sensitive enough to detect the observed differences. For example, small differences could be missed if the test is not sufficiently sensitive. The choice of an appropriate test that is adapted to the distribution of the data and the type of effects studied is therefore of great importance. It may be useful to consider alternative tests that are better suited to the specific conditions of the study, such as more robust procedures or tests that are less susceptible to within-group variance.
- **Natural variance:** The possibility that the observed differences are due to natural variation or random variation should also be considered. In any study, there is some natural variance between participants that is not due to the variables being studied. This variance can affect the signal-to-noise ratio, making true effects more difficult to identify. It is conceivable that the differences observed in this study are due to random variation rather than true differences between groups. This could particularly be the case if the sample is small or if the participant population is heterogeneous. Careful analysis of the sources of variance and consideration of additional control variables could help to better isolate such effects and understand whether the observed differences are actually meaningful.

It is important to consider these potential influencing factors and conduct further research to better understand the reasons for the lack of significance of the results.

The results of the student survey in relation to the assessment of the criteria of the end of module assessment represent an existing product that has not yet been standardized, meaning that it was not possible to draw on already validated measurement instruments. This survey is intended as a preparatory measure for the creation of grading criteria, which were subsequently developed and validated. A successful non-standardized measure such as this can form an important basis for the development and validation of a subsequent survey instrument. It provides valuable practical insights and experience that can be used to optimize the construction and operationalization of the new instrument. By analyzing and reflecting on the results and challenges of the non-standardized measure, weaknesses can be identified and addressed in order to develop a more reliable and valid instrument (Flick, 2018).

Table 7 overview outlines the quality criteria and the fulfillment indexes of the quantitative research concerning both surveys.

5.2.2 Quality criteria for qualitative research

Qualitative research is characterized by its depth and detail and requires specific quality criteria to ensure the trustworthiness and validity of the results. Ensuring the quality of qualitative research is often achieved by adhering to certain standards and criteria, which are discussed in detail in the specialist literature.

The quality of qualitative research depends on the transparency, reflexivity and plausibility of the research results (Flick, 2018, p. 125). These fundamental principles form the basis for assessing the quality of qualitative studies.

Triangulation is an important method for increasing the validity and reliability of qualitative research (Denzin, 1978, p. 291). The use of different data sources and methods can increase the diversity of perspectives in research.

- **Transparency and traceability:** The codings and their assignments were documented in detail to ensure the traceability of the analysis. According to Mayring (2014), transparency in the research process is crucial in order

TABLE 7 Overview of the quality criteria of quantitative research and its fulfillment indexes (source: own presentation).

Quality criteria	Definition	Fulfillment index
Objectivity	Objectivity is the extent to which a research result is unaffected by the researcher during implementation, evaluation, and interpretation, or if multiple researchers arrive at consistent results. Neither during the implementation nor during the evaluation and interpretation should different experts obtain different results. Implementation objectivity requires that the research result remains unaffected by the practitioner. Interpretative objectivity requires that individual interpretations do not influence the interpretation of a result.	The **objectivity of implementation** can be assumed here since the online surveys of the participants were conducted without influence from the author of this work in both cases. The **objectivity of evaluation and interpretation** is also given since the statistical programs SPSS® and Lime Survey® provided the facts.
Reliability	Reliability indicates the consistency of a measurement method. A study is considered reliable if it produces the same results when repeated under the same conditions and with the same subjects. It can be determined, among other things, through a repeat examination (retest method) or another equivalent study (parallel test method).	Regarding the online surveys of the participants following the **"Traffic Physics" curriculum** as well as **the evaluations of the criteria of the module final exams**, reliability must be excluded as these research phases are the first of their kind and the number of participants is too low. Reliability will be determined in subsequent phases using other examination methods.
Validity	Validity is the most important test quality criterion as it indicates the degree of accuracy with which a study measures what it is supposed to measure. Validity is assessed by correlating it with an external criterion. Objective and reliable instruments do not necessarily have to be valid. Validity can only be judged in relation to certain other measurements. There are different types of validity: Construct Validity, Criterion Validity, Content Validity, Ecological Validity.	The author accounted for the aspect of **validity** by ensuring that the surveys and observations in the studies were precisely tailored to the initial problem posed. The entire research process aims for an immediate confrontation with the introductory problem and the research questions.

to clearly explain the methodological approach and the decisions made.

All coding in the research process was clearly described and recorded. This made it possible to present the methodological approach and the decision-making processes transparently for external reviewers. A coding manual was created explicitly for this process.

- **Reflexivity:** Continuous reflection on one's own position and possible influence on the research results is essential. Reflexivity enables researchers to critically question their own biases and perspectives (Finlay, 2002, p. 532). This helps to minimize bias and increase the objectivity of the analysis.

  Regular self-reflection and critical discussions within the research team helped to identify and minimize potential biases. This reflexivity helped to increase the objectivity of the analysis and strengthen the credibility of the results.
- **Triangulation:** The inclusion of different data sources, methods and perspectives serves to validate the results. Triangulation strengthens the credibility of the research results by linking different strands of information (Patton, 1999, p. 1193). This methodological diversity increases the reliability and validity of the research results.

  The combination of different strands of information and methodological approaches (e.g., interviews, observations, document analysis) strengthened the reliability and validity of the research results. This enabled a comprehensive and multi-layered view of the research subject.
- **Plausibility check:** The codes and categories developed were regularly checked through peer reviews and discussions within the research team. The plausibility check by third parties can help to ensure the consistency and logic of the research results (Lincoln and Guba, 1985, p. 301).

  The quality of the analysis was further enhanced by involving external experts.
- **Dense description:** The results were presented in detail and contextualized to enable a deep understanding of the phenomena analyzed. Dense descriptions are essential to illustrate the contextuality and complexity of social phenomena (Geertz, 1973, p. 6).

By taking these quality criteria into account, the quality and trustworthiness of the qualitative research was strengthened. This ensured that the research results can serve as a sound basis for the further development of the road safety education curriculum.

5.3 Study limitations

In order to be able to precisely classify the significance and generalizability of the present study, it is essential to reflect on its methodological and content-related limitations. The following limitations should therefore be mentioned:

- **Sample size and composition**: The study is based on a relatively small sample size. This limited number could limit the generalizability of the results. In addition, the participants were exclusively teacher education students at the University of Cologne, which means that the results cannot be easily transferred to other universities or study programs.
- **Self-selection of participants**: The students voluntarily registered for the "Traffic Physics" module, which may lead to self-selection. This could mean that the participants already had a higher level of interest and prior knowledge in the field of road safety than the general student body, which could have influenced the results.
- **Non-standardized measurement instruments**: Some of the surveys and evaluations were based on non-standardized measurement instruments. Although this serves as a preparatory measure to develop a validated set of expectations, it could affect the comparability and reliability of the data collected.

- **Subjective evaluation of end of module assessments**: Students' evaluation of end of module assessments may have been influenced by subjective judgments and perceptions that arose from their own completion of the module previously. This subjectivity could limit the validity of the results with regard to the fulfillment of the criteria for the end of module assessments.
- **Time limit of the survey**: The data collection took place over a period of 3 years (2022–2024). However, changes in students' traffic behavior and attitudes could be different in the longer term. However, the long-term effects of the module were not investigated here.
- **Missing control group**: The study did not include a control group that did not have access to the "Traffic Physics" module. Without such a control group, it is difficult to clearly determine the specific influence of the module on the observed changes.
- **Influence of external factors**: External factors, such as changes in traffic policy or media reports on road safety, could have influenced students' attitudes and behavior and thus distorted the results of the study.

5.3.1 Summary

These limitations should be taken into account when interpreting the study results. Future research could address these limitations by including larger and more diverse samples, using standardized measurement instruments and including control groups, and launching a longitudinal study to increase the validity and reliability of the results.

5.3.2 Limits of the curricular content

The evaluation and further development of the "Traffic Physics" module requires careful consideration of the existing curricular content. This reveals various limitations and challenges that can influence the effectiveness and relevance of the training. The following limitations of the curricular content could be relevant:

- **Limited scope and depth of topics**: The curriculum might not cover all relevant aspects of traffic physics, resulting in students developing only a limited understanding of the subject matter. This could be particularly problematic in a rapidly evolving field such as traffic physics, where new research and technologies are constantly emerging.
- **Lack of adaptation to different levels of prior knowledge**: The curricular content may not be sufficiently differentiated to cater to the different levels of prior knowledge of the students. This could lead to some students being overwhelmed and others being underchallenged.
- **Lack of practical orientation**: A curriculum that focuses too heavily on theoretical content could neglect students' practical skills. Especially in traffic physics, where practical applications and experiments are of great importance, this could represent a significant deficit.
- **Inflexibility in the integration of new content**: Curricular content often has to be planned and approved over longer periods of time. This can mean that new and relevant topics cannot be integrated into the curriculum quickly enough, which impairs the topicality and relevance of the training.
- **Lack of interdisciplinarity**: Traffic physics is an interdisciplinary field that requires knowledge of physics, engineering, psychology and other areas. A curriculum that does not take sufficient account of this interdisciplinarity could hinder the comprehensive education of students.
- **Insufficient consideration of regional and cultural differences**: Traffic problems and solutions can depend heavily on regional and cultural contexts. A curriculum that does not take these differences into account may be less relevant and useful for students from different regions and cultures.
- **Overloading with content**: A curriculum that is too extensive can lead to students being overloaded, which could impair their learning success. Students may find it difficult to process and apply the large amount of information.
- **Lack of continuous updating and evaluation**: A curriculum that is not regularly evaluated and updated could contain outdated or no longer relevant content. This would have a negative impact on the quality and relevance of the training.

5.3.3 Limits in relation to the target group

Another crucial aspect of the study concerns the specific target group of student teachers, which may not be fully representative of the entire spectrum of future teachers. The students on the "Transport Physics" module come from a variety of study programs, including special education, upper secondary school and comprehensive school. This diversity within the target group brings with it specific challenges and requirements that could limit the generalizability of the results to other teachers. Student teachers from these areas generally have different prior knowledge, interests and pedagogical focuses. For example, special education students may have a different approach to the topics of road safety and physics than students training for upper secondary school or comprehensive school. These differences could lead to varying responses to the "traffic physics" curriculum, depending on the specific educational and subject backgrounds of the students. While the diversity in the study programs can be an enrichment for the discussion and exchange in the module, it also carries the risk that the results of the study are not fully transferable to other teachers who are not working in these specific pedagogical contexts. Teachers who teach in other types of schools or subjects could perceive the curriculum differently or set different priorities with regard to the application and effectiveness of the content taught. In order to increase the generalizability of the results, it would therefore be important to conduct similar studies with an even broader target group of teachers who have different professional backgrounds and experiences. This could also include the involvement of teachers from different educational levels or subject areas in order to investigate whether and how the "Transport Physics" curriculum works in different educational contexts. Such further studies could help to paint a more comprehensive picture of how different teachers respond to the curriculum and the extent to which the approaches developed are universally applicable.

5.4 Comparison of the results with other studies

In order to place the results of this study in a broader scientific context, it is helpful to compare them with the findings of other studies. Such comparisons can help to assess the robustness and generalizability of the results and open up possible new perspectives on the research topic.

- **Comparison with studies on road safety education**

The results of this study are partly consistent with the findings of previous studies on road safety education. For example, a study by Schubert and Kunz (2018) showed that practice-oriented modules in road safety education can increase participants' self-efficacy and safety awareness (Schubert and Kunz, 2018, p. 123–145). Similarly, a positive change in participants' attitudes and behavior in road traffic was also observed in the present study. This confirms the effectiveness of practice-oriented approaches in road safety education.

- **Comparison with studies on the design thinking approach in education**

Furthermore, Cassarino and Murphy (2018)'s ecological systems analysis illustrates that young drivers benefit from training programs that take an integrative approach. This study supports this by showing that the design thinking approach provides a methodological basis for structured problem solving and reflection. Findings by Weber and Bresges (2013a,b) already demonstrate that design thinking in traffic space analysis promotes problem awareness and creativity—skills that are also essential for prospective teachers in the field of road safety education. The use of the design thinking approach in education has been investigated in various studies. A study by Razzouk and Shute (2012) showed that design thinking can foster creativity and problem-solving skills in students (p. 330–348). The results of the present study confirm these findings in that the students were able to develop innovative solutions to traffic-related problems and showed a high level of motivation and commitment in doing so.

- **Comparison with studies on teacher training**

The present study confirms that road safety programs in teacher training have only a limited influence on the behavior or personal attitudes of prospective teachers in road traffic. Similar results were found by Faus et al. (2023), who show that although road safety training promotes awareness, without regular reinforcement it rarely brings about lasting changes in behavior. In the present study, no significant influence on the traffic attitudes of the students could be demonstrated, which points to the need for longer-term practical application and repetition, as Hatakka et al. (2002) also found. With regard to teacher education, studies by Darling-Hammond (2012) and Shulman (1987, p. 1–22) found that practice-oriented and reflective approaches can significantly improve the professionalism and teaching quality of future teachers. The present study shows similar tendencies: The application of the design thinking approach in the module "Traffic Physics" enabled students to gain practical experience and strengthen their didactic skills.

- **Methodological comparisons**

Methodologically, parallels can also be drawn with other studies. For example, the study by Johnson and Onwuegbuzie (2004, p. 14–26) emphasized the importance of using mixed methods in educational research in order to gain a deeper understanding of complex pedagogical phenomena. The present study also used both quantitative and qualitative methods to draw a comprehensive picture of the effects of the curriculum.

In Hattie's (2009) extensive meta-analysis, it is clear that instructional content that promotes immediate and practical applications is critical to sustained learning success. This finding suggests that an expectation horizon, as developed in the present study, strengthens the consistency and objectivity of assessment, but long-term behavior change may only be achieved through refinement and application across multiple lessons.

- **Differences and contradictions**

Despite these similarities, there are also differences and potential contradictions with other studies. One critical perspective on the design thinking approach is that its iterative nature can potentially lead to a lack of structure and clear outcomes by getting teams stuck in endless cycles of idea generation and testing. This criticism implies that the approach may not always be effective in developing concrete solutions. This is also discussed by Brown (2008, p. 84–92) in his analysis of the design thinking approach, where he highlights the potential challenges and limitations of the approach alongside its benefits.

Overall, comparisons with other studies show that the results of the present study are largely in line with existing research findings. The application of the design thinking approach in the "Traffic Physics" module proves to be a promising approach for promoting creative and practice-oriented learning in teacher education. At the same time, the results point to the need for further research, particularly with regard to the long-term effects and the adaptation of the approach to different target groups.

5.5 Research gap

Despite the findings from the current study, there are several areas that should be further investigated to gain a more comprehensive understanding of the effectiveness and applicability of the "Traffic Physics" curriculum and the design thinking approach in teacher education.

- **Long-term effects**

A central research gap exists in the investigation of the long-term effects of the "Traffic Physics" curriculum on the traffic behavior and pedagogical skills of teacher education students. It remains unclear to what extent the content and methods learned are integrated into the professional activities of future teachers in the long term and what lasting effects this has on road safety education in schools.

- **Comparison with other didactic approaches**

It would be valuable to systematically compare the "Traffic Physics" curriculum and the use of the design thinking approach with other didactic approaches. Such comparative studies could show which methods are particularly effective and which specific advantages and challenges are associated with the design thinking approach.

- **Differentiated target group analysis**

Further research could focus on a nuanced analysis of different target groups in order to investigate how different prior knowledge, interests and learning styles influence the effectiveness of the curriculum. Such an analysis could serve to tailor the curriculum to the needs of different groups of student teachers.

- **Integration of practical elements**

The current study could be supplemented by an in-depth investigation into the integration of practical elements, such as excursions or practical exercises in road traffic. It would be interesting to investigate how such practice-oriented elements influence students' motivation to learn and their understanding of road safety-related content.

- **Influence of cultural and social factors**

Finally, there is a research gap in the investigation of the influence of cultural and social factors on the effectiveness of the curriculum. It would be valuable to explore how different cultural backgrounds and social contexts influence the reception and implementation of the content and methods taught.

By addressing these research gaps, the understanding of the effectiveness and applicability of the "Traffic Physics" curriculum and the design thinking approach in teacher training could be significantly expanded.

6 Conclusion and outlook

The present study examined the effectiveness of the "Traffic Physics" module using the Design Thinking approach for training prospective student teachers. The study analyzed key aspects of teaching methods, the preparation of students for conveying traffic safety-related content, and the impact on individual norms, values, and attitudes toward road traffic. A central theme of the module was the safety of children on their way to school, with a particular emphasis on the vulnerability of this target group.

The results indicate that the module did not lead to significant changes in the students' own traffic behavior but did achieve a high level of acceptance for the Design Thinking approach among the students. A significant advance was made through the development of a fundamental and groundbreaking framework of expectations, which will be of great use in future teaching practice. This framework provides a structured system for the creation and assessment of curricular modules, contributing to the standardization and quality assurance in teacher education.

The results are particularly positive in the areas of prototype development, general introduction, research design, as well as traffic space analysis and traffic flow. These were consistently rated highly, underscoring the effectiveness of the Design Thinking approach. The process clearly fosters the development of creative and practical solutions and helps students develop a deep understanding of the problem and apply appropriate research methods.

6.1 Implications

The positive evaluations and thorough treatment of the task areas in the "Traffic Physics" module demonstrate that the Design Thinking approach is a promising tool for teacher education. It not only fosters creativity and problem-solving skills but also supports a systematic analysis of complex traffic issues. This leads to well-documented and practical solutions that can be applied in real-world contexts. These results suggest that the approach could also be applied in other educational modules to enable a deeper engagement with complex topics.

6.2 Open problems and future research

Despite the positive results, several questions remain unanswered. A major limitation is the lack of long-term studies on the module's impact on students' own traffic behavior. Future studies are needed to assess long-term behavioral changes to evaluate the sustainability of the module. Furthermore, studies should be conducted in different educational contexts and with various target groups to assess the generalizability of the results and consider potential adaptations to the module.

The generalizability of the results is also limited due to the specific target group of student teachers, who may have a particular affinity for traffic safety and physics. External variables, such as personal attitudes and prior experiences, may have influenced the results, complicating their interpretation. Additionally, the long-term effects of the module were not sufficiently studied, leaving it unclear whether the students will apply the methods they learned in their future teaching practice. The complex Design Thinking approach might have overwhelmed some students, suggesting that it may not be equally suitable for all learning styles. Moreover, the integration of the module into the overall curriculum remains unclear, which could limit the isolated application of the approach. Finally, the subjectivity of the raters' evaluations could have led to varying assessments, highlighting the need for standardized assessment tools. Further investigation into additional teaching methods that complement the Design Thinking approach could help to fully realize the potential of this innovative teaching strategy. It would also be beneficial to further develop the practical aspects of teaching, such as the analysis of accident vehicles, to enhance the relevance and clarity of the content being taught.

6.3 Conclusion

The present study compellingly demonstrates the effectiveness of the Design Thinking approach in the "Traffic Physics" module and underscores its significant potential for enhancing teacher education. The approach not only fosters students' creativity and problem-solving skills but also enables a systematic and in-depth analysis of complex traffic issues. This leads to a practice-oriented education that produces teachers who are well-prepared for the challenges of real-world classroom settings. The results of this study provide a solid foundation for the further development and adaptation of teaching methods in traffic safety education, with the clear goal of sustainably improving both traffic safety and the understanding of traffic physics. The success of the Design Thinking approach in this module suggests that its application could extend well beyond the current context, potentially having a similarly transformative impact in other educational fields.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the study involving humans in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and the institutional requirements.

Author contributions

SB: Writing – original draft, Writing – review & editing. AB: Writing – review & editing, Funding acquisition, Methodology, Resources, Supervision.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1471022/full#supplementary-material

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3.3 Zusammenfassung der Ergebnisse

Im Rahmen dieser Untersuchung wurden die Forschungsfragen schlussendlich umfassend analysiert und die folgenden zentralen Erkenntnisse gewonnen:

Studie 1: Die Ergebnisse zeigen, dass die inhaltlichen Bedarfe der Teilnehmer*innen durch den Einsatz spezifischer Methoden aus der kognitiven Verhaltenstherapie erfolgreich aufgefangen werden konnten. Zu den angewandten Methoden gehörten

- die kognitive Umstrukturierung zur Reflexion von Verhalten, Einstellungen, Normen und Werten,
- Disputationstechniken zur Aufdeckung von Widersprüchen im Denken,
- Problemlösetrainings zur Kontrastierung von Handlungsmöglichkeiten,
- Methoden zur Erklärung von Sicherheitskonzepten und zur Stärkung der Selbstwirksamkeit, sowie
- der Sokratische Dialog.

Diese Methoden halfen den Teilnehmer*innen, sich kritisch mit Risiken und vermeintlicher Sicherheit auseinanderzusetzen und ihre Entscheidungsoptionen zu erweitern.

Gleichzeitig formulierten die Ergebnisse einen Bedarf an die Moderierenden, klare Antworten auf zentrale Fragen nach Antworten im Zusammenhang mit realen Unfällen im Rahmen einer Unfallverhütungskampagne geben zu können. Diese Fragen umfassen

- Unfall-Vermeidungsstrategien,
- die Folgen von Alkohol- und Drogenkonsum,
- den Einfluss des eigenen Gesundheitsstatus auf die Verkehrssicherheit,
- Gesetzeskunde und
- Unfallnachsorge.

Die Kombination aus methodischer Unterstützung und inhaltlicher Aufklärung trug wesentlich dazu bei, die notwendigen Informationen zu vermitteln und das Sicherheitsbewusstsein der Teilnehmer nachhaltig zu stärken.

Studie 2: Die Untersuchung zeigte, dass das veränderte Konzept eines Unfallauto-Exponats im Vergleich zu "Crash Kurs NRW" zu deutlich niedrigeren Reaktanzwerten führte, was darauf hinweist, dass diese Methode weniger Widerstand bei den Teilnehmer*innen erzeugte. Die Anwesenheit der Polizei hatte dabei keinen signifikanten Einfluss auf die Reaktanz, weder steigernd noch reduzierend. Darüber hinaus konnte das unterrichtliche

Nachbereitungskonzept erfolgreich zur angestrebten Verhaltensänderung beitragen, indem es den Teilnehmer*innen half, sicherheitsrelevante Botschaften besser zu verarbeiten und in ihrem Verhalten umzusetzen. Schließlich erwies sich das Exponat eines Unfallautos als geeignet, physikalische Themen im Unterricht aufzugreifen und darstellend zu erläutern, insbesondere wenn eine zielgerichtete Moderation erfolgte, die die physikalischen Prinzipien klar hervorhob.

Studie 3: Es konnte festgestellt werden, dass die Integration des Moduls Verkehrsphysik in die Lehramtsausbildung weder das Verhalten noch die persönlichen Einstellungen angehender Lehrer*innen im Hinblick auf den Straßenverkehr signifikant beeinflusste. Allerdings konnten Kriterien identifiziert werden, die eine strukturierte Darstellung des Design-Thinking-Ansatzes zur Analyse eines Verkehrsraums und seiner Lösungsfindung in einer Modulabschlussprüfung ermöglichen. Darüber hinaus konnte ein grundlegender Erwartungshorizont für die Bewertung dieser Prüfungen entwickelt werden, der durch weitergehende Forschung noch verfeinert werden kann.

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4. Übergreifende Diskussion

4.1 Bedeutung der Ergebnisse im Kontext der bestehenden Literatur

Furchtappelle, die oft in Verkehrssicherheitskampagnen verwendet werden, können unterschiedliche psychologische Reaktionen hervorrufen. Während sie einerseits dazu beitragen können, die Wahrnehmung von Risiken zu erhöhen und präventives Verhalten zu fördern, können sie andererseits auch Abwehrmechanismen und Reaktanz auslösen (Dahlgren, P., 2020). Diese dualen Effekte müssen bei der Gestaltung von Präventionskampagnen sorgfältig berücksichtigt werden, um deren Effektivität zu maximieren und unerwünschte Gegenreaktionen zu minimieren.

Die Rolle der Massenmedien in der Verhaltensänderung wurde ebenfalls hervorgehoben. Studien haben gezeigt, dass Medienkampagnen effektiv dazu beitragen können, gesundheitsbewusstes Verhalten zu fördern, insbesondere wenn sie strategisch geplant und zielgruppenspezifisch ausgerichtet sind (Bonfadelli H., Friemel T.N., 2010). Die Integration solcher Medienstrategien in Verkehrssicherheitskampagnen könnte daher deren Wirksamkeit weiter steigern.

Die Ergebnisse der Studien zeigen, dass emotionale Appelle, wenn sie durch gezielte Nachbereitung ergänzt werden, eine signifikante Wirkung auf das Verhalten junger Verkehrsteilnehmer*innen haben können (von Beesten S., Bresges A., 2022). Dies steht im Einklang mit früheren Forschungsergebnissen, die die Bedeutung emotionaler Ansprache und

kognitiver Nachbereitung in Präventionskampagnen betonen (Rossmann C., Hastall M., 2019; Koehler, M. et al., 2022).

4.2 Implikationen für die Praxis

Die Erkenntnisse dieser Dissertation haben wichtige Implikationen für die Gestaltung von Verkehrssicherheitskampagnen und die Ausbildung von Lehrkräften. Sie zeigen, dass die Einbindung von praktischen Demonstrationen und die Anwendung von Design Thinking dazu beitragen können, die Effektivität von Präventionsmaßnahmen zu erhöhen und nachhaltige Verhaltensänderungen zu fördern.

4.3 Einschränkungen der Studien

Eine der Einschränkungen dieser Studien war die begrenzte Stichprobengröße, die die Verallgemeinerbarkeit der Ergebnisse beeinträchtigen könnte. Zudem wurden die Studien in spezifischen Kontexten durchgeführt, was die Übertragbarkeit der Ergebnisse auf andere Settings und Zielgruppen einschränken könnte.

4.4 Vorschläge für zukünftige Forschung

Zukünftige Forschung sollte Langzeitstudien umfassen, um die Nachhaltigkeit der beobachteten Verhaltensänderungen zu untersuchen. Zudem sollten unterschiedliche pädagogische Ansätze und deren Wirksamkeit in verschiedenen kulturellen und sozialen Kontexten verglichen werden.

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5. Weiterführende Forschungsansätze

Für weiterführende Forschung im Bereich der Verkehrsunfallprävention und Sicherheitsbewusstsein an Schulen wird ein ganzheitlicher Ansatz vorgeschlagen, der mehrere Schlüsselaspekte umfasst:

Langzeitstudie zur Nachhaltigkeit von Verhaltensänderungen

Eine umfassende Untersuchung über mehrere Jahre hinweg, um die Langzeitwirkungen von Schulungsprogrammen wie „Crash Kurs NRW“ auf das Verhalten der Teilnehmer*innen zu verstehen. Dies könnte durch regelmäßige Nachbefragungen und Beobachtungen der tatsächlichen Verkehrssicherheitspraktiken erfolgen.

Vergleich unterschiedlicher pädagogischer Ansätze

Eine vergleichende Analyse verschiedener pädagogischer Methoden und Ansätze zur Verkehrsunfallprävention. Hierbei könnten neben traditionellen Präventionsveranstaltungen auch neue digitale Lehrformate und interaktive Lernmethoden in den Fokus genommen werden, um deren Effektivität und Akzeptanz zu bewerten.

Integration psychologischer Aspekte

Untersuchungen zur Integration psychologischer Erkenntnisse in die Lehrpläne zur Verkehrssicherheit. Dies könnte die Berücksichtigung von Emotionen, Einstellungen und sozialen Normen umfassen, um die Wirksamkeit von Präventionsmaßnahmen zu optimieren. Insbesondere die Theorie der erlernten Hilflosigkeit könnte hier Anwendung finden, um zu verstehen, wie Schüler*innen auf wiederholte negative Erlebnisse im Verkehr reagieren und wie man ihnen helfen kann, ein Gefühl der Kontrolle und Selbstwirksamkeit zu entwickeln (Seligman E.P., Petermann F., 2016).

Mehr Einbeziehung von Stakeholdern und Schulen

Eine Studie, die die Perspektiven und Erfahrungen der Schulen und anderer beteiligter Stakeholder wie Eltern, Lehrkräfte und Verkehrsexperten einbezieht, um die Umsetzbarkeit und Effektivität von Verkehrssicherheitsinitiativen in Schulen zu verbessern und Best Practices zu identifizieren. Petermann und Petermann (2018) betonen die Bedeutung einer umfassenden Verkehrs- und Mobilitätserziehung in der Schule, die alle relevanten Stakeholder einbindet, um nachhaltige Verhaltensänderungen bei Schüler*innen zu fördern (Petermann F., Petermann U., 2018). Steffen (2012) unterstreicht zudem die Notwendigkeit interdisziplinärer Ansätze in der Verkehrssicherheitsforschung, um die vielfältigen Einflussfaktoren auf das Verhalten der Verkehrsteilnehmer*innen zu berücksichtigen und effektive Präventionsstrategien zu entwickeln (Steffen W., 2012).

Internationale Vergleiche und Best-Practice-Analysen

Eine Analyse von internationalen Best-Practice-Beispielen in der Verkehrsunfallprävention an Schulen, um zu verstehen, welche Ansätze in verschiedenen kulturellen und gesellschaftlichen Kontexten am effektivsten sind. Studien zur Wirksamkeit von Gesundheitspräventionskampagnen, wie die von Zatonski und Herbec (Zatonski M., Herbec A., 2016) zur AIDS-Prävention, zeigen, dass kulturell angepasste und zielgruppenspezifische Ansätze besonders erfolgreich sein können. Dies könnte zur Entwicklung global anwendbarer Leitlinien für Verkehrssicherheitsprogramme beitragen.

Barrierefreiheit und Zugänglichkeit

Die Durchführung einer Studie zur Gewährleistung der Barrierefreiheit von Verkehrssicherheitsinitiativen für Schüler*innen mit körperlichen Beeinträchtigungen blieb an dieser Stelle unberücksichtigt. Dies könnte die Anpassung von Lehrmaterialien, Schulungsformaten und Veranstaltungsorten umfassen, um sicherzustellen, dass alle Schüler*innen gleichermaßen am Programm teilnehmen können.

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6. Eidesstattliche Erklärung

Erklärung zur Dissertation

gemäß der Promotionsordnung vom 12. März 2020

Hiermit versichere ich an Eides statt, dass ich die vorliegende Dissertation selbstständig und ohne die Benutzung anderer als der angegebenen Hilfsmittel und Literatur angefertigt habe. Alle Stellen, die wörtlich oder sinngemäß aus veröffentlichten und nicht veröffentlichten Werken dem Wortlaut oder dem Sinn nach entnommen wurden, sind als solche kenntlich gemacht. Ich versichere an Eides statt, dass diese Dissertation noch keiner anderen Fakultät oder Universität zur Prüfung vorgelegen hat; dass sie - abgesehen von unten angegebenen Teilpublikationen und eingebundenen Artikeln und Manuskripten - noch nicht veröffentlicht worden ist sowie, dass ich eine Veröffentlichung der Dissertation vor Abschluss der Promotion nicht ohne Genehmigung des Promotionsausschusses vornehmen werde. Die Bestimmungen dieser Ordnung sind mir bekannt. Darüber hinaus erkläre ich hiermit, dass ich die Ordnung zur Sicherung guter wissenschaftlicher Praxis und zum Umgang mit wissenschaftlichem Fehlverhalten der Universität zu Köln gelesen und sie bei der Durchführung der Dissertation zugrundeliegenden Arbeiten und der schriftlich verfassten Dissertation beachtet habe und verpflichte mich hiermit, die dort genannten Vorgaben bei allen wissenschaftlichen Tätigkeiten zu beachten und umzusetzen. Ich versichere, dass die eingereichte elektronische Fassung der eingereichten Druckfassung vollständig entspricht.

Teilpublikationen:

Publikation 1: Wirksamkeit der Verkehrssicherheitsprävention in Schulen

- von Beesten S., Bresges A. (2022): Evectiveness of road safety prevention in schools. Front. Psychol. 13:1046403. doi: 10.3389/fpsyg.2022.1046403.

Publikation 2: Wirksamkeit pädagogischer Interventionen zur Minimierung der Reaktanz bei der Verkehrsunfallprävention

- von Beesten S., Bresges A., Lubert D. (2024): Effectiveness of educational interventions in minimizing reactance in traffic accident prevention. Front. Educ. 8:1276380. doi: 10.3389/feduc.2023.1276380.

Publikation 3: Wirksamkeit geeigneter Lehrmethoden zur Vorbereitung von Lehramtsstudenten auf die Vermittlung verkehrssicherheitsrelevanter Inhalte

- von Beesten S., Bresges A. (2025): The effectiveness of teaching methods for preparing teacher education students to teach road safety-related content. Front. Educ. 9: https://doi.org/10.3389/feduc.2024.1471022

22.08.2024, Silke von Beesten
Datum, Name und Unterschrift

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7. Darstellung der Eigenanteile

In der vorliegenden Arbeit wurden verschiedene Studien und Analysen durchgeführt, deren Anteile im Folgenden dargelegt werden.

Artikel 1 und 3: Die Forschung für diese Artikel wurde vollständig von mir selbst durchgeführt. Dies umfasst die Konzeption der Studien, die Datenerhebung, Analyse, Auswertung sowie die Interpretation der Ergebnisse. Sämtliche methodische und inhaltliche Entscheidungen wurden zunächst eigenständig getroffen und die Artikel wurden in Eigenverantwortung verfasst. Dabei erfolgte eine kontinuierliche Beratung und Betreuung durch meinen Doktorvater Herrn Prof. Dr. André Bresges, der mir bei methodischen Fragen sowie inhaltlichen Überlegungen unterstützend zur Seite stand.

Artikel 2: Die empirische Datenerhebung vor Ort wurde durch mich durchgeführt. Die Analyse, Auswertung und Interpretation der Daten wurden im Rahmen der Masterarbeit von Frau Daniela Lubert durchgeführt, die für die Konzeption und Durchführung verantwortlich war. Meine Rolle bestand in beratender Unterstützung während des gesamten Prozesses, wobei ich methodische Ratschläge gab und bei der Interpretation half. Die Zusammenarbeit wurde eng mit Prof. Dr. André Bresges abgestimmt, um sicherzustellen, dass die Analyse den wissenschaftlichen Standards sowie dem Bewertungsrahmen der Prüfungsleistung entsprach.

Die hierbei gewonnenen Ergebnisse wurden als Grundlage zum vorliegenden Artikel verwandt, der dann in einer deutlich umfangreicheren Form durch mich gefertigt wurde.

Nachfolgende Grafik verdeutlicht die aufgeschlüsselten Arbeitsanteile:

Autor	Aufgabe	Zeitraum	Publikation
Silke von Beesten, M. Sc.	Themenfindung und Zielsetzung Literaturrecherche Datensammlung Datenanalyse Interpretation der gewonnenen Ergebnisse Erstellung der ersten Entwürfe Überarbeitung und Feinschliff Einreichung des Manuskripts Nachbereitung Überarbeitung nach Gutachterkommentaren Finalisierung und erneute Einreichung **Koordination mit Co-Autoren:** Sicherstellung, dass alle Autoren über den Fortschritt informiert sind und ihre Aufgaben rechtzeitig erledigen. **Formatierung und Stilüberprüfung:** Sicherstellen, dass das Manuskript den formalen Anforderungen der Zielzeitschrift entspricht. **Erstellung von Abbildungen und Tabellen:** Visuelle Darstellung der Daten und Ergebnisse. **Schreiben von Abstracts und Zusammenfassungen:** Erstellung prägnanter Zusammenfassungen der Arbeit. **Literaturverzeichnis und Zitationen:** Korrekte und vollständige Angabe aller Referenzen und Zitationen. **Vorbereitung von Präsentationen:** Erstellung von Präsentationsmaterialien für Konferenzen oder Seminare. **Ethikanträge und Genehmigungen:** Einholen und Verwaltung der notwendigen ethischen Genehmigungen für die Forschung. **Feedback-Runden organisieren:** Einholen und Integrieren von Feedback von Betreuern und Kollegen.	Januar 2022 - Dezember 2024	Alle Publikationen
Daniela Lubert, M. Ed.	Datenerhebung - Analyse und Interpretation	Juli 2022 - Februar 2023	Publikation 2
Prof. Dr. Andre Bresges	Betreuung im Rahmen der Promotion mit den Aufgaben: Beratung bei Themenfindung und Zielsetzung Unterstützung bei der Literaturrecherche Überwachung der Datensammlung Beratung bei der Datenanalyse Feedback zu den ersten Entwürfen Beratung bei der Überarbeitung und Feinschliff Unterstützung bei der Einreichung des Manuskripts Beratung bei der Nachbereitung Unterstützung bei der Überarbeitung nach Gutachterkommentaren Beratung bei der Finalisierung und erneuten Einreichung	Januar 2022 - Dezember 2024	Alle Publikationen

Abbildung 1: Übersicht der Autorenaufgaben, eigene Darstellung

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8. Datensicherung und Zugänglichkeit

Gemäß Promotionsordnung der Mathematisch-Naturwissenschaftlichen Fakultät der Universität zu Köln vom 12. März 2020 ist in der Dissertation darzulegen, wie Daten und Materialien gesichert und zugänglich sind.

Die Daten für diese Dissertation sind wie folgt gesichert: auf einem externen USB-Stick, der in einem Safe der Sicherheitsstufe 0 EN 1143-1 an privater Anschrift mit Bodenverankerung gesichert ist. Der Zugang obliegt via Zahlencode nur der Verfasserin.

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9. Verzeichnis der benutzten Hilfsmittel

Für die Erstellung von Grafiken, Analysen und Auswertungen der wissenschaftlichen Ergebnisse wurden verschiedene Hilfsmittel verwendet:

- SPSS® zur statistischen Analyse der erhobenen Daten.
- MAXQDA® zur qualitativen Datenanalyse, insbesondere zur Codierung und Auswertung der durchgeführten Modulabschlussprüfungen und der Analyse von Textdaten in der Entwicklung des Erwartungshorizontes.
- LimeSurvey® zur Durchführung statistischer Auswertungen und Verwaltung der empirischen Umfragen.
- DeepL® zur Unterstützung bei der Übersetzung und sprachlichen Überprüfung von Texten.
- Microsoft Excel® für die Organisation und Visualisierung von Daten sowie für grundlegende statistische Berechnungen.
- Microsoft PowerPoint® zur Erstellung von anschaulichen Grafiken zur Darstellung der Ergebnisse.
- ChatGPT zur Quellenrecherche sowie für die Erstellung einer Zeitplantabelle (s. Folgeseite)

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10. Zeitplan

In den folgenden Tabellen werden sowohl die zeitlichen Abläufe der drei Publikationen dargestellt, sowie die Aufgabenverteilung der drei publizierenden Autoren.
Der Zeitplan setzt ein bei der fokussierten Konkretisierung zum ersten Artikel. Infolge der in 2020 einsetzenden Coronaproblematik mussten bereits im Vorfeld statt gefundener Planungen umgestellt und entlang des Forschungsthemas neu ausgerichtet werden. Hierzu gibt es im ersten Fachartikel Hinweise.
Bei den Autoren handelt es sich um

1. Silke von Beesten, M.Sc. – Promotionsabsolventin
2. Daniela Lubert, M. Ed. – unterstützende Studierende in einem Fachartikel
3. Prof. Dr. André Bresges – betreuender Doktorvater

Phase	Aufgabe	Artikel 1: "Effectiveness of Road Safety Prevention in Schools" (2022)	Artikel 2: "Effectiveness of educational interventions in minimizing reactance in traffic accident prevention " (2024)	Artikel 3: "The effectiveness of teaching methods for preparing teacher education students to teach road safety-related content" (2024)
Vorbereitung und Recherche	Themenfindung und Zielsetzung	Jan 20	Mär 22	August 2023 - Oktober 2023
	Literaturrecherche	Januar 2020 - 1. Februar 2022	März 2022 - Februar 2023	August 2023 - Oktober 2023
Datensammlung und -analyse	Datensammlung	Februar 2020 - Juni 2020	Juli 2022 - Februar 2023	Juni 2022 - Juli 2024
	Datenanalyse	Februar 2021- März 2022	Juli 2022 - Februar 2023	Juni 2022 - Juli 2024
Schreibprozess	Erstellung der ersten Entwürfe	März 2022 - April 2022	Juli 2022 - August 2023	Juni 2023 - Juli 2024
	Überarbeitung und Feinschliff	April 2022 - Mai 2022	Aug 23	8. April - 15. Mai 2024
Einreichung und Nachbereitung	Einreichung des Manuskripts	27. Jun 22	11. Aug 23	Jul 24
	interne Nachbereitung	28. Juni - 20. Juli 2022	12. August - 12. September 2023	28. Juli - 15. August 2024
Review-Prozess	Begutachtung durch Fachkollegen	21. Juli - 20. August 2022	13. September - 13. Oktober 2023	16. August - 15. September 2024
	Überarbeitung nach Gutachterkommentaren	21. August - 20. September 2022	14. Oktober - 14. November 2023	16. September - 15. Oktober 2024
	Finalisierung und erneute Einreichung	21. September - 10. Oktober 2022	15. November - 5. Dezember 2023	16. - 31. Oktober 2024
Publikation		**10. Dez 22**	**20. Feb 24**	

Abbildung 2: Zeitplan der Publikationen, eigene Darstellung

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11.3 Abbildungsverzeichnis

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12. Danksagung

Im Jahr 2009 wurde ich als Polizeibeamtin mit der Kampagne „Crash Kurs NRW“ beauftragt. Zu diesem Zeitpunkt war das Projekt noch ohne Namen, klare Inhalte oder Strukturen, und seine zukünftige Entwicklung war seinerzeit noch ungewiss. Wir erhielten den Auftrag, eine

Präventionskampagne zu entwickeln, die sich an einem Konzept aus England orientierte. Aus diesen Anfängen entstand eine weitreichende Kampagne, die viel öffentliche Aufmerksamkeit erringen sollte. In dieser Zeit lernte ich meinen heutigen Doktorvater Prof. Dr. André Bresges kennen. Damals hätte ich nicht erwartet, dass ich später einmal mit einem didaktischen Kontext zu diesem Projekt promovieren würde, da ich zu jener Zeit noch keinen Hochschulabschluss besaß.

Heute, an diesem Punkt angekommen, erfüllt es mich mit tiefer Dankbarkeit, auf diese Reise zurückzublicken.

Mein besonderer Dank gilt daher meinem Doktorvater, Herrn Prof. Dr. André Bresges, der mir den Mut gab, diesen Weg zu beschreiten und mich als Polizistin der Wissenschaft und Lehre näherbrachte.

Ich danke dem Vorsitzenden des Prüfungsausschusses, Herrn Prof. Dr. Benjamin Rott, für die Übernahme der Prüfung, sowie Herrn Prof. Dr. Andreas Schadschneider für die Begutachtung meiner Arbeit. Frau Dr. Cristal Schult danke ich für ihren Beisitz.

Ein weiterer besonderer Dank gilt Frau Christine Quambusch, Assistentin der Geschäftsführung am Institut für Physikdidaktik, für ihre stetige Unterstützung, für ihre Hilfe in letzter Sekunde und für die souveräne Leitung inmitten des geschäftigen Treibens. Es ist mir eine große Ehre, das Team des Instituts für Physikdidaktik zu kennen und Teil dessen sein zu dürfen! Besonders erwähnen möchte ich Jochen Scheld und Jannik Henze, die mich bei der Technik, dem Angstgegner schlechthin, und der Logistik der Terminierungen von Probanden vor Ort unterstützt haben.

Mein ebenso großer Dank gilt dem Institut für Physikdidaktik, das durch die Kostenübernahme für die Publikation der drei Fachartikel das Promovieren in dieser Form für mich ermöglicht hat. Diese Unterstützung war von unschätzbarem Wert und hat maßgeblich dazu beigetragen, die Forschungsergebnisse einer breiteren wissenschaftlichen Gemeinschaft zugänglich zu machen.

Mein tiefster Dank gilt schlussendlich meiner Familie, die mich allgegenwärtig unterstützt und ermutigt hat, dieses Ziel trotz meines vorangeschrittenen Alters zu verfolgen. Meinen beiden Kindern danke ich für ihre Geduld und ihr mildes Lächeln, während sie ihre Mutter oft am Rechner sahen – und sich vielleicht ein wenig in ihrem eigenen Bildungsweg inspiriert fühlen.

Zu guter Letzt danke ich all den lieben Menschen, die hier nicht explizit genannt sind, die mich jedoch in den langen Jahren begleitet haben und stets wärmende Worte fanden.