BLENDED LEARNING IN HIGHER EDUCATION FROM A SUSTAINABILITY PERSPECTIVE

Marieke Versteijlen

Propositions

1. Higher education should design (blended) education in such a way that it not only achieves its educational objectives but also maximizes its contribution to achieving a climate-neutral world.
   (this thesis)
2. Organizing on-campus education two days per week in a blended design decreases student travel to and from campus.
   (this thesis)
3. The cooperation of researchers and educational practitioners in an Educational Design Research approach ensures the relevancy of its scientific results to educational practice.
4. Students' social interaction with lecturers and fellow students promotes their learning.
5. The environmental cost of travel should be factored into the price of each mode of transportation.
6. Women's access to and participation in STEM workplace environments is constrained by structural barriers such as gender stereotypes, hostile work environments and work-family imbalance.

Propositions belonging to the thesis, entitled

Blended learning in higher education from a sustainability perspective

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Blended learning in higher education from a sustainability perspective

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Thesis

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Preface

My life's journey to this PhD has been 'a long and winding road'. As a young girl, I never considered a technical study, as so many girls before, during and after me. It took me seven years, during which I studied Dutch language and literature, was engaged in social activism, worked in a music store and organised music concerts in a youth centre. After this period, I gathered enough self-confidence and motivation to study electrical engineering and graduated in speech technology. Since then I have worked in the field of Informatics, first as a programmer, and later on as an educator at a University of Applied Sciences (UAS). I have always enjoyed having the technical skills to create software products and pass these skills on to students. Nevertheless, something was missing. I fulfilled my potential to be an engineer, but not my ambitions to employ my knowledge and skills to make this world more sustainable. I am deeply concerned about climate change. An opportunity presented itself with a research call of SURF (Dutch ICT-cooperation of Education and Research) asking for research proposals to explore the potential of ICT to support sustainability in educational processes in Dutch higher education. My proposal got accepted and the exploration that followed led to this PhD study. The path I followed was that of an external PhD still working as a lecturer and researcher at Avans UAS.

The SURF exploration revealed the potential of online learning to lower the carbon footprint of higher education institutions. For me, this was an eye-opener. The more I read about the subject the more I realised that an efficient educational design, taking account of commuting students, could probably lower its environmental impact as well as improve educational quality. Avans UAS already started to reflect critically on and improve its educational and business processes regarding sustainability but did not know how to deal with one of the largest contributors to the carbon footprint, namely student commute. "Your research is all we have" John Theeuwes, responsible for sustainable transport policy at Avans, once told me. Taking commuter students into account in the organisation of education to reduce the ecological footprint seemed to be a blind spot, not only at Avans but also in the academic literature and among all the representatives of Dutch higher education I spoke to. It is probably because it touches on several disciplines: education, transport and sustainability. Balancing these three disciplines was the most challenging task during my PhD research. I experienced several 'out of scope' assessments of the editors or reviewers of academic journals. In most cases, only journals with a focus on sustainability recognised the added value of the interdisciplinary approach. I found this hard to swallow. I believe that climate urgency forces the (academic) world to consider sustainability aspects in every field and describing these aspects should not be limited to journals on sustainability.

Another challenge presented itself with the arrival of the COVID-19 pandemic. My research was in the stage of studying the design and implementation of a blended study programme taking account of the travel movements of students and suddenly, only online learning was

possible and travel was discouraged. Therefore, I had to adjust my research plan. One of the advantages was that lecturers and students underwent a steep learning curve regarding online learning and teaching possibilities. These challenges and other bumps in the road could be overcome thanks to the help and encouragement of several people. I mentioned the narrow-mindedness of several editors and reviewers but this mindset was contrary to that of my two promoters and supporting professor at Avans UAS. Their open-mindedness inspired me to be creative and follow my own path. I could never have completed this PhD without them for which I am deeply grateful. When I first met Arjen Wals, my promotor at Wageningen University & Research, I was very unsure of my academic research skills after a failed cooperation with my first promotor, but Arjen took me seriously in all my ideas, thus building up my confidence and inspiring me to dare think out of the box. He introduced me further to the world of sustainability-oriented learning. This broadened my environmental perspective of blended learning to the opportunities it can offer for developing sustainability competencies. His open-mindedness showed by immediately welcoming the idea of inviting Bert van Wee as a promotor to guide me through travel behaviour subjects. I will never forget my first conversation with Bert van Wee, my promotor at Delft University of Technology, at that point only meant for orientation purposes. It made me realise that there is far more to student commute than the carbon emissions it causes. I left the room with an introductory book about the transport system. Later on, when I approached Bert to be my second promotor, sending him my research proposal, to my surprise, after a few hours he agreed and returned my research proposal with comments. This story is typical of the guidance I got from Bert. Always on time and opening up the world of travel behaviour for me. He often encouraged me to dig deeper through his comments on my writings, also proposing new directions to take.
From the start and even before, Marleen Janssen Groesbeek, my supporting professor at Avans UAS, has been the stable and crucial factor throughout my PhD research. She facilitated and supported me during the process and I wonder if I would have completed this PhD without her. We share a passion for making the world more sustainable and she was a great example for me that this cannot be limited to your own field. Being a professor in Finance and Accounting, she welcomed an ICT lecturer to her knowledge group to conduct research on sustainability, education and transport subjects. Also, after this PhD, we will continue our cooperation and I am looking forward to it. Marleen also supported me in the first difficult years of my PhD at the Open University of the Netherlands (OU). After the SURF exploration, I found Professor Paquita Perez Salgado of the OU as a kindred spirit and promotor. She introduced me to the world of science and my first published article in response to the SURF exploration (Chapter 2) is a result of this cooperation. I want to thank her and Anda Counotte for all the feedback on my writing. Still, differences of opinion forced me to look elsewhere to continue with my PhD research. This was not an easy decision and probably would not have turned out so well without the help and encouragement of my PhD intervision group. Ella, Jack and Eefje, thank you for all the intensive and eye-opening conversations we had.

I already mentioned the Finance and Accounting knowledge group surrounding Marleen Janssen Groesbeek. It was a place of discussion and criticism helping me to shape my thoughts. On top of that, they taught me a lot about finance and accounting! Thank you for thinking along with me. My special thanks go to Tim Willems, Dorien de Graaff and Tom Vos. Tim and Dorien made it possible and were participants in designing and implementing a sustainable blended minor (Chapter 5). Tom helped me to promote my research. He came up with the idea to write an opinion article for a newspaper on my topic and together we made this happen. This article got published and even caught the attention of a national radio program "Dit is de dag" in which I could discuss sustainable blended learning. I already mentioned John Theeuwes, now retired, but at the time of my student travel behaviour study, he was responsible for sustainable transport policy at Avans UAS. He acted as moderator at all my focus groups with students. Thank you for this and also for all the inspiring conversations. I also want to thank Avans UAS, in particular the Academy of Technology and Design, for providing the opportunities and time to conduct this PhD research. It was not always easy to fit me into the schedule of teaching. Gratitude and everlasting love go to my family and friends. My partner Frits always emphasized the importance of my research and commented on and criticized my work. It was sometimes not what I wanted to hear but it always made me think twice. During my research, my children Tomas and Rosa were the same age and study level as the students I studied. This made it possible to mirror my ideas to their experiences and they even tested my student surveys. Thank you all!

"Be the change you are trying to create"

- Mahatma Gandhi.

CHAPTER 1 General introduction

1.1 Setting the stage

In 2015, 193 countries adopted 17 sustainable development goals (SDGs) as a part of an agenda aimed "to take the bold and transformative steps which are urgently needed to shift the world onto a sustainable and resilient path" (United Nations, 2015, p. 5). One of the 17 SDGs is SDG 4 which focuses on creating quality education for all as one key mechanism to help realize all the other SDGs. Higher education (HE) is one sphere of education that can play a crucial role in contributing to the SDGs. Since its institutions have roots in local communities and are globally interconnected with other institutions, they can help a wide stakeholder community to understand and address sustainability challenges (Purcell, Henriksen, & Spengler, 2019), not only by education but also through institutional transformation aligned with the SDGs. This "whole-institution approach" embeds sustainability in all aspects of the institution (Kohl et al., 2021), that is, education, research, own sustainability-related behavioural practices, community engagement, leadership and ethos, and, professional development of staff (Mathie & Wals, 2022).

In this thesis, the focus lies on both contributing to SDG 4 which connects a university´s curriculum and pedagogical arrangements and to SDG 13 which calls for urgent action to combat climate change and its impacts and connects with the institution´s own sustainability-related behavioural practices. The latter means for a higher educational institution (HEI), improving education to create awareness on climate change mitigation (target 13.3) as well as integrating climate change measures into policies, strategies and planning (target 13.2) (United Nations, 2015).

One of the measures HE could take, in relation to SDG 13, is lowering its carbon footprint. A main contributor to the carbon footprint is the emissions caused by commuting to and from an HEI, travel of international students, and faculty travel to international meetings and conferences (Valls-Val & Bovea, 2021). While HEIs tend to focus on international staff travel to conferences and seminars with all kinds of incentives to choose from low-carbon transport modes, they tend to ignore the much more frequent local commute-related student travel (Hopkins, Higham, Tapp, & Duncan, 2016). This thesis is particularly concerned with this aspect of a university´s carbon footprint and investigates how student travel to and from campus can be reduced by combining online with on-campus learning without compromising the quality of education (SDG 4). In other words, how can a different organisation of educational activities contribute to lowering the associated travel emissions? Digital technology makes studying anytime and anywhere possible. This creates opportunities for a learning configuration in which teaching and learning can be delivered on-campus or online at a location of your own choice. When teaching and learning on campus in this learning configuration will be clustered on a few days per week, it may lower the commute-related

travel of students. A learning configuration which combines online with on-campus learning is called blended learning. Another aspect of blended learning appeared during the COVID-19 pandemic, when most HEIs (67 % worldwide) needed to make a rapid transition to, so-called, 'emergency remote teaching' (Marinoni, Van't Land, & Jensen, 2020), revealing deficiencies in existing infrastructure and the availability of devices for online/distance learning, and teacher training. Also in the Netherlands, the COVID-19 pandemic severely impacted HE and, indeed, the execution of this PhD research as it made the intended development of a programme with on-campus education clustered over two days and designed according to the developed pedagogical design principles almost impossible. The government restrictions changed the blend to mainly online education. It was not what the design team aimed for, but the unanticipated pandemic provided an opportunity to study the impact of these restrictions on student's attitude towards online learning and commute-related travel. It is quite possible that these COVID-19 restrictions were a trigger for a change of attitude of students (Van Wee & Witlox, 2021).

In this PhD thesis, the potential of blended learning is studied for reducing travel-related carbon emissions of students while enhancing the educational quality using sustainability-oriented learning as a backdrop. Blended learning has extensively been studied, but rarely from a sustainability perspective and almost certainly not using a holistic approach, that is, taking educational, organisational and environmental aspects of a blended learning design into account. These different aspects will be explained in the next sections.

Lowering the carbon footprint of an HEI by decreasing student travel

This research starts from the assumption that a carefully constructed design can be conducive to decreasing the commute-related travel of students. This assumption is based on the work of Caird et al. (2015), showing that distance-based HE teaching models (distance, online) achieve carbon reductions of 83 per cent in comparison with on-campus models (in-class, ICT-enhanced). This is largely due to student commuting. Their analysis also revealed that a third of the carbon emissions associated with a blended ICT-enhanced face-to-face teaching model was induced by air travel between home and study location (Caird, Lane, Swithenby, Roy, & Potter, 2015; Caird & Roy, 2019). In this thesis, international student travel is not considered, because the studied blended learning design assumes a clustering of on-campus learning on a few days per week, making a scenario in which students attend these sessions by air travel, highly unlikely. This would be different if on-campus learning were organized on a consecutive period during, for instance, a semester, after (or before) supplemented by online learning, as is the case with the studied blended ICT-enhanced face-to-face teaching model of Caird et al. (2015). The study of Caird et al. (2015) notes a significant difference in carbon emissions between online and in-class education but does not clarify how a blended design with education clustered on two days per week will affect student travel. This depends on the student's travel behaviour and the student's attitude towards learning on campus. It may be so that on the remaining (online learning) days a student will travel to the institution anyway,

for instance, for studying in the library (Regalado & Smale, 2015). Another possibility is that a student will travel more to non-study activities when having more choices about where and when to study. This travelling does not contribute to the carbon footprint of an HEI but still is an undesired result. This increased travelling will happen according to the concept of constant travel time budgets (TTB), which assumes that people have, on average, a stable TTB of around 60-75 minutes per person (Van Wee, 2015). Students are a socio-economic group with distinctive characteristics (generally unmarried, no children, a lower (or even no) income young of age) (Zhou, J. P., 2012) and since TTB is constant only at the most aggregate level it is unclear whether this also applies to this specific group.

In the few academic studies about student travel behaviour, the focus lies on a modal shift from commuting by car to less carbon-intensive modes, especially in studies in car-dependent countries such as Canada (Whalen, Páez, & Carrasco, 2013), United States (Zhou, J. P., 2012) or Australia (Hancock & Nuttman, 2014). Besides a modal shift, the Intergovernmental Panel on Climate Change (IPCC) also recommends, "avoiding journeys where possible—by, for example, (…) utilizing advanced information and communication technologies (ICT)" (IPCC, 2014, p. 603). In the Netherlands, most students already commute by the more sustainable option, that is public transit or cycling. Only eight per cent of Dutch students own a car (Kampert, Molnár-in't Veld, Nijenhuis, & van der Spoel, 2018). Probably the reason for the Dutch sustainable mode choice is that in the Netherlands, students get a public transport permit, free of charge. Also, a high-quality infrastructure (for travelling by car, bicycle and public transport) and a strong cycling culture (Belgiawan et al., 2014) will be of influence. Nevertheless, a blended design may influence the chosen travel mode and so, a modal shift is considered in this thesis, but the main focus lies on the IPCC recommendation 'avoiding journeys'.

According to the Theory of Planned Behaviour (Ajzen, 1991), the student's choice to make a trip to campus derives from an intention depending on attitude, social norms and perceived behavioural control. Attitude refers to how a person evaluates or appraises a particular behaviour. Social norms refer to the perceived social pressure and perceived behavioural control to the perceived capability of performing the behaviour (Ajzen, 1991). In this PhD study, this theory is used to analyse the decision process when a student is expected to attend a learning activity on campus.

Enhancing the quality of education

Blended learning may make a difference when considering HEI's carbon footprint, but its design should maintain, or ideally improve educational quality. The issue with blended learning is that there is hardly any prescription on how to design this learning configuration besides being a mix of online and on-campus learning (Boelens, De Wever, & Voet, 2017). Allen and Seaman (2007) classified blended learning as an educational unit in which 30-

79 per cent of the content is delivered online. This classification covers the organisational part, but attention should be paid to the pedagogical approach because blended learning changes or extends the mode of interaction with fellow students, lecturers and content (Bliuc, Goodyear, & Ellis, 2007). These iterative interactions are depicted by Laurillard (2009) in the Conversational Framework. This general framework combines instructionism, social learning, constructionism and collaborative learning, providing a simplified representation of learning and teaching in any form, conventional and technology-enhanced (Laurillard, 2009). This framework can be used to design learning activities for a blended learning configuration (Laurillard, 2013). In addition, to ensure that the necessary cycles of interaction between student and lecturer, and fellow students take place, there are also social aspects to consider. Vaughan and Garrison (2008) introduced the Community of Inquiry Framework which specifies the process of integrating social, cognitive, and teaching elements of a community of students. Another area of concern is the opportunities blended learning offers for studying anytime and anywhere. This asks for more self-regulation skills from students (Boelens et al., 2017). Low-achieving students in particular have less control over their learning process and need more guidance (Owston, York, & Murtha, 2013).

In this PhD research, the objective is to study the opportunities of blended learning to decrease student travel. To decrease this travel, at least 30 per cent of the educational content in a blended design should be delivered online (Allen & Seaman, 2003), substituting on-campus learning a few days per week. To enhance and monitor the educational quality of this blended design, a detailed pedagogical framework is needed (Boelens, Voet, & De Wever, 2018) This study aims to develop pedagogical design principles to guide the design of blended learning and enhance educational quality.

Promoting sustainability-oriented learning

According to the United Nations (2015), one of the aspects of educational quality is also how an educational design stimulates acquiring sustainability competencies which are needed for students to address the complex challenges of this climate-changed world and to create a sustainable future. A competency is a combination of knowledge, skills and attitude, needed to accomplish the desired educational outcome (Lozano, Barreiro-Gen, Lozano, & Sammalisto, 2019; Wiek, Withycombe, & Redman, 2011). In the last decade, several sustainability competencies have been proposed in academia which Brundiers et al.(2021) collated and synthesized into a set of key sustainability competencies. These competencies provide the students with the necessary knowledge and skills to analyse systems across different domains, anticipate future challenges, apply ethical values, design and implement transformative interventions and engage stakeholders in the process (Brundiers et al., 2021; Wiek et al., 2011). Sustainability-oriented learning teaches students to collaborate, involve stakeholders with diverse perspectives, and integrate social, environmental and economic aspects when performing a task that involves solving real-world problems, thus taking a

constructivist approach to learning (De Kraker, Corvers, & Lansu, 2014; Tejedor et al., 2019). It helps to promote environmental awareness and environmental consciousness among students (Dimante, Tambovceva, & Atstaja, 2016). This is because students are exposed to various environmental issues and sustainability practices, which can help to change their attitudes and behaviour towards the environment. Moreover, sustainability-oriented learning can also encourage students to engage in environmental activism and advocacy, thereby promoting environmental sustainability in their communities and beyond (Wals, 2019). To meet these expectations, a student should be prepared for lifelong learning (Brundiers et al., 2021; Jackson, 2012).

It is an ongoing question in academia what pedagogical approaches are needed to develop these competencies (Lozano, Merrill, Sammalisto, Ceulemans, & Lozano, 2017) and if the blended learning design is supportive of these approaches. Some benefits of blended learning look promising. The strength of blended learning is that it fosters a virtual space next to the physical space which, if designed properly, enforce each other. The virtual space opens new opportunities for collaboration, discussion, knowledge acquisition, simulation and so on. The possibility to collaborate in an online environment removes spatial barriers and students and teachers from different cultures and disciplines can work together cost-effectively and sustainably without having to travel (De Kraker et al., 2014). Another benefit of virtual space is that it opens the way to all kinds of multimedia content via the internet, supporting lifelong learning (Robelia, Greenhow, & Burton, 2011). Noting that students need to learn where and how to find reliable knowledge because the amount of knowledge on the internet is increasing exponentially (Taylor, 2022).

This PhD research considers the acquisition of sustainability competencies as one of the aspects of educational quality and this has been taken into account in developing design principles for blended learning.
In summary, many HEIs aspire to contribute to the SDGs and that means sustainability as a guideline on all aspects of the institution. In this dissertation, the blended learning configuration, commonly used in Dutch HE, is studied as a measure to lower the carbon footprint by decreasing commute-related student travel.

1.2 Aim and research questions

This PhD research aims to find directions on how to design learning in higher education from both a sustainability and an educational perspective. The potential of a blended learning design to reduce the carbon footprint of an HEI by decreasing commute-related student travel will be studied. This design should not compromise the educational quality and support sustainability-oriented learning. This leads to the following central question: How can sustainability-oriented blended learning in higher education be designed to reduce carbon emissions due to student travel behaviour without compromising educational quality?
The following sub-questions will guide this research with the first two being more travel-related and the second two being more education-related:

1. What impact could the adoption of online learning in (Dutch) higher education have on decreasing its carbon footprint through reduced student commuting, and on educational quality?
2. What are the considerations and (de)motivators of students influencing their travel mode choices and their decisions whether to travel to their institution or to study (online) from home or a place that does not require travelling?
3. Which design principles and recommendations can be extracted from scientific theory and empirical studies about blended and sustainability-oriented learning?
4. How can a sustainable blended learning study programme be designed and implemented in higher education?

1.3 Research design

In this PhD research, scientific understanding shapes the design of a solution to a real problem. This corresponds with Educational Design Research (EDR) methodology which aims at both scientific and practical solutions and is well-suited to deal with a complex reality (McKenney & Reeves, 2018). Designing and implementing blended learning from a sustainability perspective is such a complex reality. It exhibits the features of a complex social intervention, as defined by Pawson et al. (2004). Integrating blended learning is susceptible to the motivations and considerations of various stakeholders (management, lecturers and students) and needs to be modified under varying circumstances such as study phase, subject and policy of an HEI. As a result, there is no fixed formula for developing and executing a blended learning approach, and it requires ongoing discussion and input at all stages. Probably for this reason, EDR is a widely-used methodology to study (blended) learning interventions (Reeves, 2006; Van den

Akker, Gravemeijer, McKenney, & Nieveen, 2006; Wang, F. & Hannafin, 2005). Characteristics of EDR are 1. pragmatic, i.e. informing and improving educational practice; 2. grounded in relevant scientific research; 3. interactive, i.e. involving educational stakeholders; 4. iterative cycles of analysis, design and implementation; 5. integrative, i.e. using different research methods and 6. contextual, i.e. connecting results with the design process and setting (Wang, F. & Hannafin, 2005).

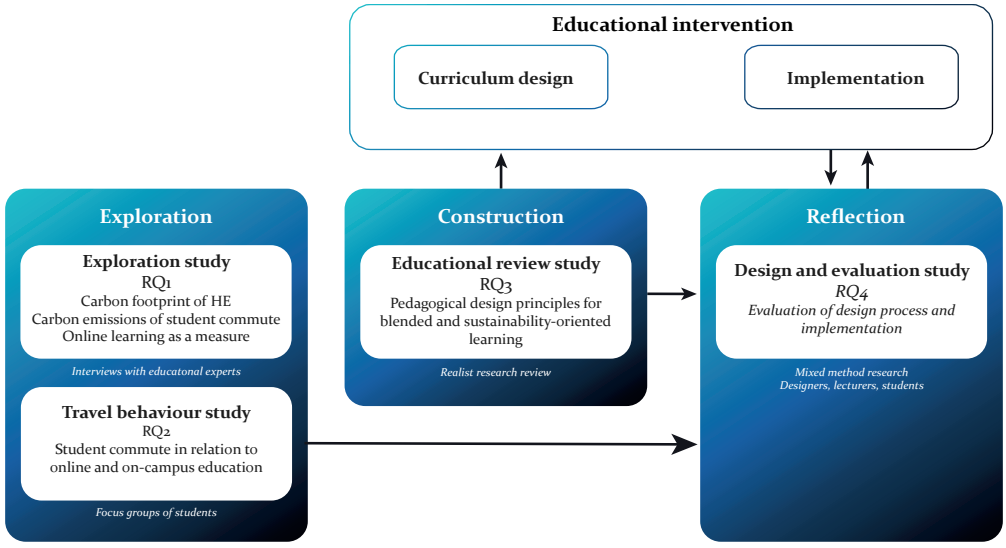
The design of this PhD study, based on the EDR methodology of McKenney and Reeves (2018), meets most of these characteristics but not all. For pragmatic reasons, choices had to be made. A significant part (Exploration stage in Figure 1.1) is dedicated to understanding the initial situation, because the sustainability perspective on blended learning is a relatively unknown research area. The consequence was that testing and refinement of the prototype and the design principles in different contexts was not possible. Only one prototype has been designed, implemented and evaluated, but the building of this prototype is guided by a thorough theory-building study, a so-called realist synthesis review (Pawson, Greenhalgh, Harvey, & Walshe, 2004). Initially, this review started as a means to support the team designing a blended study programme, described in Chapter 5. The team members did not have much experience designing blended learning and especially asked for experiences as a result of other blended learning designs. Finally, this resulted in a realist research review in which pedagogical design principles and associated recommendations were developed. These design principles are developed from well-established theoretical works about blended/online learning (Ellis & Goodyear, 2013; Garrison & Vaughan, 2008; Laurillard, 2013) and evaluated against the experiences with these principles studied in existing empirical research on blended and sustainability-oriented learning (38 studies). Just like EDR, the realist research review method aims to design future interventions, is pragmatic and contextual, assuming "What works for whom, in what circumstances, in what respects, and how" (Pawson et al., 2004, p. 5) and therefore fits well in this research design. Since these studies were conducted simultaneously, not all the results of the educational review could be included in the implementation of the blended study programme.

Figure 1.1 depicts the full research design. The results of both the Exploration and the Construction stages are input for the development of the initial design principles to be applied in the Reflection stage. The developed design principles from the construction stage were also input for the design of the sustainable blended study programme (educational intervention). The experiences with the design and implementation of this study programme have been incorporated into the evaluation study. This evaluation can be used to enhance this study programme or future iterations in different contexts.

This EDR study used multiple research methods to arrive at a design for sustainable blended learning. As stated before, blended learning from a sustainability perspective is a relatively

unexplored field of research. Therefore, in this PhD research during the Exploration stage, the perceptions, opinions and experiences of various stakeholders are studied using qualitative methods which are most suitable for obtaining an in-depth understanding. For extracting theoretical knowledge, the qualitative data were inductively analysed and validated by existing scientific research. This deeper insight into student travel behaviour in relation to their learning on campus was used to obtain indicators of changed student attitudes towards online learning and commuting after COVID-19 by conducting a baseline measurement survey as the start of a mixed method approach in the Reflection stage.

Figure 1.1. Overview of the PHD research design



In the Exploration stage, the subject is explored from a broad perspective. Educational and organisational professionals from three universities of applied sciences and two universities were interviewed. In the remaining stages, the sampling frame contains students and staff from Avans University of Applied Sciences (Avans UAS). Avans UAS has a wide range of bachelor studies and a large number of students (26,725 full-time students, 09-10-2018) divided over three cities ('s-Hertogenbosch, Tilburg, Breda). Dependencies of travel behaviour with respect to residence or bachelor study can thus be included in the research. In addition, cooperation is guaranteed as this PhD research is closely aligned with the objectives of Avans UAS with respect to sustainability and digital technology. We limit ourselves to full-time students because part-time students combine, in most cases, work with study and have other interests. Full-time students also represent the majority in HE and they spend more time at the institution, receiving more face-to-face education than part-time students.

1.4 Overview of the thesis

In **Chapter 2** the first sub-question has been explored, that is, what impact could the adoption of online learning in (Dutch) higher education have on decreasing its carbon footprint through reduced student commuting and on educational quality? (RQ1). In this chapter, two basic concepts used in this PhD research are explained. The first is the carbon footprint and how this is measured and reported on by an internationally accepted GHG accounting and reporting standard for companies and organisations, the Greenhouse Gas Protocol Initiative (WBCSD, 2014). The second concept is online and blended learning with a definition, classification and characteristics. After clarifying these concepts, findings regarding the impact of student and staff travel on the carbon footprint from reports of six Dutch HEIs are compared with the results from studies from other countries from which data could be gathered. Dutch ICT and sustainability professionals are interviewed to explore the measures taken to reduce the impact of commuting and if the use of digital technology is one of these measures. Educators and policymakers are interviewed to weigh the pros and cons of online learning in HE to get a sense of whether the introduction of online learning is appropriate as a measure to reduce student commuting.

In **Chapter 3** the balance between online and on-campus learning is considered from the perspective of students. Students' considerations and (de)motivators influencing their travel mode choices and their decisions whether to travel to their institution or to study (online) from home or a place that does not require travelling are explored (RQ2). In addition, account is taken of the possibility that studying at home stimulates a student to increase travelling to non-study activities. Dutch students from different bachelor studies and study phases talked about these considerations in five focus groups. This study resulted in a conceptual model "Travel for learning" in which the considerations underlying the short-term behavioural travel choices of individual students are depicted (Figure 3.1). This model is initially based on theoretical concepts of travel behaviour and evaluated with the findings of the focus groups.

In **Chapter 4**, the educational review study is described. The objective of this review is the development of design principles and to guide the design of sustainability-oriented blended education in higher education (RQ3). This study has a two-step approach. Firstly, applying a realist research review approach, pedagogical design principles and associated recommendations for blended learning are developed and secondly, these principles are evaluated and adapted using academic research on sustainability competencies, pedagogical approaches to develop these competencies and empirical studies on online learning and sustainability.

In **Chapter 5** the research is synthesized in a sustainable blended study programme which utilizes the initial design principles that emerged from the preceding studies (RQ4). This blended study programme can be considered the first prototype delivered by this educational design-based research. The initial pedagogical design principles were tested and refined during the design and implementation of an economic business minor at Avans University of Applied Sciences. In addition, the corresponding student travel behaviour and a possible attitude change of students towards online learning and commuting due to the restrictions of the COVID-19 pandemic are evaluated.

In the final **Chapter 6** key findings are discussed. Also, implications for educational policy are distilled from the research and suggestions for future research are offered. In addition, this chapter contains a critical retrospective reflection on the way the research was set up and executed and a brief discussion of the impact of unexpected factors that influenced the study, mainly the outbreak of COVID-19 during the research.

CHAPTER 2 Pros and cons of online education as a measure to reduce carbon emissions

Published as: Versteijlen, M., Salgado, F. P., Groesbeek, M. J., & Counotte, A. (2017). Pros and cons of online education as a measure to reduce carbon emissions in higher education in the Netherlands. Current Opinion in Environmental Sustainability, 28, 80-89.

Abstract

Dutch institutions of higher education have to meet stringent requirements for energy efficiency and reduction of carbon emissions imposed by the national government and through voluntary agreements on energy efficiency. This exploratory study reports the relative contribution of student (and staff) travel to the carbon emissions of Dutch higher education institutions (HEIs) and examines the arguments for and against online education as a means to reduce the carbon impact of student travel. Data on carbon emissions using the greenhouse gas (GHG) protocol, published by HEIs, were gathered and analysed. A comparison with data from other countries is presented. It was found that the contribution of the so-called Scope 3 emissions (travel-related) to the total carbon footprint of the HEIs is between 40 and 90 per cent of the Dutch HEIs that were investigated. Online education (80 per cent or more digitalisation of the educational processes) greatly decreases the carbon impact of student and staff travel. A series of interviews were held with HEI professionals in online education and ICT/sustainability. The interviews were analysed using the grounded theory approach. The professionals report as pros of online education its flexibility and power to personalise the educational needs of individual students and the possibility to extend the learning environment with digital media. As an argument against online education professionals mention the non-committal behaviour of students. Only a few HEI professionals recognize the connection between online education and its potential for strongly reducing carbon emissions.

2.1 Introduction

Under the United Nations Framework Convention on Climate Change in 2015 (the Paris Agreement) 197 countries have committed themselves to keep global warming well below 20C above pre-industrial levels (UN, 2015). In April 2016 the European Union ratified the Paris Agreement. For the Netherlands, this means a reduction of greenhouse gas (GHG) emissions of 85–95 per cent in 2050 (baseline 1990) (Vuuren, Boot, Ros, Hof, & Elzen, 2016). The awareness of the necessity of a responsible attitude towards the environment is growing in Dutch higher education (HE). An example of this attitude is the signing of a long-term agreement (LTA) with the government to improve energy efficiency by 30 per cent from 2005 until 2020 (RVO, 2016a; RVO, 2016b) in 2001. Improving energy efficiency and using energy sources with less carbon emissions lead to a reduction of GHG emissions. However, an HEI may not only be held responsible for its own direct GHG emissions but also for the emissions as a consequence of its activities. One of these emission sources is student (and staff) travel. With the term 'student travel' we designate all travelling associated with their study, such as the daily commute between student residence and their HEI, the travel between student residence and main home residence, and all other travelling for study activities, including going abroad to take courses. Transport is known to have a significant environmental impact. The Intergovernmental Panel on Climate Change (IPCC) states that 23 per cent of global GHG emissions (in 2010) can be attributed to (passenger and freight) transport (IPCC, 2014). Given the opportunities of online education, the current state of technology and the need for a sustainable travel policy, the choice for delivering online education for Dutch HEIs would seem logical (Perez Salgado, 2008). However, up to now online education has not been widely introduced at HEIs in the Netherlands. The study presented in this article explores the following aspects:

1. The carbon emissions associated with student (and staff) travel of several Dutch HEIs,
2. The pros and cons related to implementing online education in Dutch HE, according to interviewed educational and ICT/sustainability professionals at HEIs.

This exploration consists of an analysis of reported GHG emissions from HEIs and results from in-depth interviews with HEI professionals.

The outline of this article is as follows. In the section 'Review of literature' we provide definitions and background information on reporting carbon emissions caused by student and staff travelling, and on online education. The approach (with its limitations) is explained in the section 'Methods'. In the section 'Results' we present several types of results: an analysis

of the carbon emissions related to student travel and commute of staff of HEIs, the measures and difficulties to reduce carbon emissions for travelling, and the pros and cons of online education through an analysis of interviews held with HEI professionals. In the last section, we end with a summary and conclusions, and propose suggestions for further research.

2.2 Review of literature

Measuring and reporting carbon emissions

One way of measuring the environmental impact an activity has on its surroundings is to measure its carbon footprint. A definition of the carbon footprint is: "a measure of the exclusive total amount of carbon dioxide (CO_2) emissions that is directly or indirectly caused by an activity or is accumulated over the life stages of a product" (Wiedmann & Minx, 2008, p. 4). Carbon dioxide is an important anthropogenic contributor to the GHGs, and often carbon dioxide equivalents (CO_2e) are used to express the amount of GHGs.

The Greenhouse Gas Protocol Initiative (WBCSD, 2014) is an internationally accepted GHG accounting and reporting standard for companies and organisations. It provides a guideline that companies can use to quantify and report their GHG emissions. The GHG protocol divides the emission sources into three scopes (Table 2.1). In Table 2.1 we show some examples of Scope 3 emissions, including emission sources associated with student and staff travel According to the GHG protocol reporting on Scope 3 emissions is optional. Institutions can choose which categories they wish to report on. This makes it difficult to compare Scope 3 emissions across institutions

Table 2.1. Classification of greenhouse gas emission sources based on the GHG protocol (WBCSD/WRI, 2014).

Scope	Description	Examples
Scope 1	Direct emissions from sources that are owned and controlled by the institution	Heating and cooling systems, vehicles (owned by the institution)
Scope 2	Indirect emissions from the generation of the purchased electricity consumed by the institution	Purchased electricity
Scope 3	Other indirect emissions as a consequence of the activities of the institution, but that occur from sources not owned or not controlled by the institution	Waste, procurement, education-related student travel, commute of staff, business travel

Carbon emissions due to student travel

Internationally there are only a few environmental studies in which GHG emissions of HEIs are calculated. These studies are based on the GHG protocol, so the accounting of Scope 3

emission sources is optional and therefore the system boundary can be different (Baboulet & Lenzen, 2010; Ozawa-Meida, Brockway, Letten, Davies, & Fleming, 2013; Townsend & Barrett, 2015). Studies on the environmental impact of HEIs often do not include student travel as one of the sources of carbon emissions (Baboulet & Lenzen, 2010; Ozawa-Meida et al., 2013; Townsend & Barrett, 2015). Ozawa-Meida et al. (2013) included indirect emissions due to student and staff commute, business travel, students' trips home, and visitor travel in their calculations for a UK university. In the academic year 2008/2009 they report 300 kg CO_2e emissions per student for student commute and 750 kg CO_2e emissions per staff member for staff commute. The total travel-related emissions for this specific UK university is around 15 000 Ton CO_2e and that is about 30 per cent of the overall emissions of the university.
Townsend and Barrett (2015) base their calculations of the carbon footprint of another UK university on expenditure data, that is to say: determined by the university's spending policy. They do not include travel emissions because of the complexity of gathering reliable travel data from staff and students (Townsend & Barrett, 2015). Research from the United States (US) (Bailey & LaPoint, 2016; Klein-Banai & Theis, 2013) seems to confirm the difficulty of obtaining reliable travel data at HEIs. Bailey and LaPoint (2016) and Klein-Banai and Theis (2013) state that these data have a high degree of 'inaccessible data and methodological uncertainty' (Bailey & LaPoint, 2016, p. 7), because 'it may be based on surveys, parking permit counts, travel vouchers and various other sources of data' (Klein-Banai & Theis, 2013, p. 36). Bailey and LaPoint (2016) reported for a US university in 2013 550 kg CO_2e emissions (per student per year) for student commute and 750 kg CO_2e emissions (per staff/faculty member per year) for staff/faculty commute. It follows that comparing Scope 3 emissions has to be done with great care.

Roy et al. (2008) and Caird et al. (2015) in the UK used a different approach to calculate travel emissions in a project they called SusTEACH (Sustainability Tools for the Environmental Appraisal of the Carbon impacts of HE Teaching Models using ICTs). The carbon emissions of the HEIs were not measured or calculated according to the GHG protocol (which includes waste, procurement, etcetera). They identified five emission sources within a course, namely student travel, ICT, paper and print, residential energy (that is: energy used by studying at home) and campus site operations. Subsequently, they calculated the carbon emissions per student per 100 study hours for each of these sources in HE courses with different levels of ICT intensiveness. Caird et al. (2015) classified these levels into five teaching models (Section 'Online education and a classification') to examine the transformative role of ICT. Their findings are that cam- pus-based courses (face-to-face with or without ICT- enhancement) consume considerably more energy and thus lead to high carbon emissions in comparison with distance-based courses, which are either distance or online courses. These achieve an 85 per cent (Roy, Potter, & Yarrow, 2008) and 84 per cent (Caird et al., 2015) reduction of carbon emissions with respect to face-to-face courses. One of the largest contributors to the reduction is student travel (Caird et al., 2015; Roy et al., 2008). In absolute travel-related emission values,

the face-to-face model results in about 130 kg CO_2 and the online teaching model in about 2 kg CO_2 per student per 100 study hours (Caird et al., 2015) (please note that these are expressed in terms of CO_2, not in CO_2e). To our opinion, this research (Caird et al., 2015; Roy et al., 2008) is carried out with great transparency and accuracy. However, their calculations are not at the institutional level, but at course level (in kg CO_2 per 100 study hours). The reduction online education might achieve becomes even more apparent extrapolating the calculations of Caird et al. (2015) to an academic year (1200 study hours). The student travel-related emission value of a face-to-face model is about 1500 kg CO_2 and the value of an online model is about 25 kg CO_2 per student per year. Across teaching models (the average is calculated by Caird et al. (2015)) the student travel-related emissions are about 630 kg CO_2 per student per year. This value is comparable to the measurements of Ozawa-Meida et al. (2013), if one also adds to the commute of students the UK-based and international student travel; the 300 then increases to 480 kg CO_2e per student per year. Both methods (GHG protocol and SusTEACH project) used for calculating carbon emissions of student travel, either for courses or for institutions, lead to the conclusion that student travel is one of the largest carbon emitters. In addition, a positive environmental impact of online or distance education on student travel emissions is observed.

An additional aspect that deserves attention is the travel mode. Students and staff can use different modes for travelling, such as (in descending order regarding the amount of GHG emissions): privately owned cars, public transport (tram, underground, bus, train), (electronic) bicycle, and walking. Comparing the exact GHG emissions of the travel modes has to be done with care, because this is dependent, for example, on congestion on the road, time of day, and age of the car. Moreover, there are differences between countries: for example, in the Netherlands, all trains run on renewable energy and therefore have no GHG emissions (since 2017). Research into the travel mode of students in the United States (US) (Zhou, J. P., 2012), Canada (Whalen et al., 2013), Australia (Hancock & Nuttman, 2014) and New Zealand (Hopkins et al., 2016) indicates a high car dependence of off-campus students, for example, in the US the single-occupancy car is the transport mode for 50–90 per cent of off-campus students (Gudz, Heckathorn, & Thigpen, 2016; Hancock & Nuttman, 2014; Meyerson & Sholly, 2009). This is in strong contrast with student travel in the Netherlands. Figures from 2014 indicate that only about 10 per cent of all Dutch students owned a car (Centraal Bureau voor Statistiek[CBS], 2015). Since 1991 all students of HE or students older than 18 years receive a free public transport permit and as a result, most students travel by public transport. In the UK at Leeds University the main mode of transport is public transport, even if students live more than 5 miles away from the university (University of Leeds, 2021). Not only financial motives (free travel permit, paid parking) or trip characteristics (distance, time of travel) influence the travel mode choice (Zhou, J. P., 2012). In Australia, Kerr et al. 2010) show that car dependency is influenced by psychological factors, such as behavioural intention (students' attitude, norms, ease of access) and commuting habit (Kerr, Lennon, & Watson, 2010).

Another aspect relevant to student travel-related emissions is the growing inflow of international students in HE. In the Netherlands, in 2016 there were about 42 000 international students, which is about 16 per cent of all university students (VSNU [Association of Dutch Universities]; URL: http://www.vsnu.nl/f_c_internationale_studenten. html). This has an environmental effect: air travel has a significant impact in terms of carbon emissions. A case study in the UK (Davies, Jonathan, 2015) shows that eight per cent of international students of all the institution's students can account for 10 per cent of the institution's total carbon footprint. If the course is delivered partly online, this makes hardly any difference, because students still have to travel long distances to attend the few remaining face-to-face meetings (Caird et al., 2015). Another possibility for international courses is the use of virtual mobility, where students participate in international courses without travelling and this is expected to reduce carbon emissions considerably (Pérez Salgado, de Kraker, Boon, & Van der Klink, 2012).

To summarise, in order to decrease the large environmental impact of student travel, one of the possibilities is to change the travel mode of students to a less carbon-intensive mode of travelling. However, the travel mode choice is influenced by many factors, financial as well as psychological and in the case of international travel the alternatives are limited. Another strategy to reduce student travel emissions is the use of online education and this seems to have great potential.

Online education and a classification

As online education is identified as enabling the reduction of carbon emissions, we will focus in this section on online education and its characteristics.

In HE, the interest in online education is growing. Since 2004 the New Media Consortium (NMC) started publishing an internationally recognized annual (Horizon) report about the impact of emerging technologies on teaching and learning within learning-focused organisations. In 2012, the Horizon Report Higher Education stated: "Education paradigms are shifting to include online learning, hybrid learning and collaborative models." (Johnson, Adams, & Cummins, 2012, p. 4), mentioning online education for the first time as one of the trends.

However, it should be noted that to reduce student travel carbon emissions, it is imperative that online education literally is 'education at a distance', whereby students do not (or hardly) travel to their institution to take courses, that is, location-independent. If one would add online learning facilities on top of existing face-to-face activities instead of replacing them, the result would be an increase in the environmental impact, because of the additional energy consumed by ICT facilities for the online courses (Coroama, Moberg, & Hilty, 2015; Robinson, Kemp, & Williams, 2015). Furthermore, online learning is more than delivering content

location-independently. According to Ally (2004), the process of learning and the pedagogical approach, whilst interacting with lecturers and fellow students, is just as important (Ally, 2004). Moore and Kearsley (2011) do not speak of 'distance learning' but of 'distance education' in order to emphasize the physical distance between teaching and learning (Moore & Kearsley, 2011). Our definition of online education is derived from Ally (2004) and Moore and Kearsley (2011):

> *Online education is distance education using the internet to create a learning environment, in which a student interacts with content, lecturer and other students during his/her learning process in order to acquire knowledge and competencies.*

The extent to which online education is delivered online in a course can be used to classify the type of the course. The common term 'blended learning' is generally defined as a combination of online and face-to-face learning. However, describing it this way is vague and can be misleading (Bliuc, Goodyear, & Ellis, 2007), because as shown in Table 2.2, a diverse type of courses falls within this description. In the annual Sloan survey of online learning in the United States, Allen and Seaman (2003) present a classification of course delivery methods, which is shown in Table 2.2. In this classification blended learning is reserved for courses in which 30–79 per cent is delivered online; an online course typically consists of 80–100 per cent of online activities and delivery (Allen & Seaman, 2003).

Table 2.2. Classification of learning courses according to Allen and Seaman (2003).

Proportion of Content Delivered Online	**Type of Course**	**Typical Description**
0%	Face-to-face	Course with no online technology used. Content is delivered in writing or orally in a classroom.
1 to 29%	Web Facilitated	Course that uses web-based technology to facilitate what is essentially a face-to-face course. Uses a course management system (CMS) or web pages to post the syllabus and assignments, for example.
30 to 79%	Blended/Hybrid	Course that blends online and face-to-face delivery. Substantial proportion of the content is delivered online, typically uses online discussions, and typically has some face-to-face meetings
80+%	Online	A course where most or all of the content is delivered online. Typically has no or very few face-to-face meetings.

Caird and Lane (2015) depict a different classification in teaching models, namely Face-To-Face, ICT-Enhanced Face-to-face, Distance and ICT-enhanced Distance and Online (Caird

& Lane, 2015). This has the advantage that it includes distance education (print-based materials) in the classification. Although we acknowledge the value of the classification of Caird and Lane (2015), it does not clarify to what extent in the ICT-enhanced teaching model digitalisation is used to supplement rather than substitute face-to-face teaching, and thus it does not seem to make different categories between the web-facilitated and blended/hybrid learning courses. Therefore, for the remainder of this article, we follow the classification of Allen and Seaman (2003). In contrast to web-facilitated courses, blended/hybrid educational design is more than just adding ICT enhancements to face-to-face courses. Bliuc et al. (2007) state that it requires a fundamental redesign of the pedagogical approach, because blended education changes or extends the mode of interaction with fellow students, lecturers and content. Garrison and Vaughan (2008) add that in contrast with fully online education, in a blended learning environment students are shifting between direct (face-to-face) and ICT-mediated communication (Garrison & Vaughan, 2008).

With respect to online education, a digital learning environment (DLE) is a substantial part of the learning environment of a student. The DLE should not only support the delivery of learning materials, but the whole process of learning in a flexible and accessible manner and should be ubiquitous (Brown, Dehoney, & Millichap, 2015; Moisey & Hughes, 2008). This corresponds with the functionality a 'Next-Generation-Digital-Learning- Environment' (NGDLE) can offer. The core functionality of an NGDLE must address interoperability and integration, personalisation, learning analytics, collaboration and accessibility (Brown et al., 2015).

Almost all Dutch HEIs started to use DLEs at the beginning of the 21st century, but, according to the study by Jacobs (2013), they do not use the possibilities of ICT for learning and instructional processes to its full potential. Jacobs (2013) concludes that digitalisation in learning environments seems to be dependent on the improvisation of dedicated individual lecturers and isolated projects (Jacobs, 2013).

2.3 Methods

This explorative study is meant as a first orientation to identify the important issues related to the impact of online education on the mobility of students and staff. Quantitative data on GHG emissions from the HEIs were gathered and analysed. In addition, qualitative data are obtained by interviewing nine carefully selected HE professionals and confirmed in an expert meeting with eight different (zero overlaps) experts.

In the Netherlands, an HEI can be either a university or a university of applied science (UAS). A UAS has professionally oriented bachelor and master programmes, whereas a university has

scientifically oriented bachelor and master programmes, with more emphasis on research. About 1/3 of the Dutch students are university students and 2/3 are UAS students. In most regions in the Netherlands, there is a UAS with a wide range of study programmes serving regional students.

The carbon footprint data of the selected HEIs (Utrecht UAS, Utrecht University, Erasmus University Rotterdam, Rotterdam UAS, University of Amsterdam, Amsterdam UAS) were obtained from official internal policy documents or from official data from the website of the corresponding institution and they were discussed (if necessary) with the professionals in order to be able to assess the data. In the Netherlands, several HEIs are actively pursuing a carbon reduction program. The HEIs that have undertaken a serious effort to reduce carbon emissions are still learning and although they have data to share, these are not always comparable. In addition, the data regarding student travel of the HEIs in the Netherlands are not produced with the same reliability: these are estimates based on different methods, extrapolated from travel surveys from other comparable institutions, and sometimes the source is not even mentioned.
In order to obtain information on attitudes and issues with respect to student travel and online education, semi-structured interviews were held with nationally carefully selected professionals in HEIs as the means of data- collection. The selection process was supported by SURF (the collaborative ICT organisation for Dutch education and research), which has Special Interest Groups in the areas of Green ICT and online education. The professionals work at the following HEIs: Utrecht UAS, Avans UAS, Open University of the Netherlands, Rotterdam UAS, HAN UAS, Radboud University Nijmegen. This method of semi-structured interviews is well suited for a first exploration of beliefs and motives. The interviews were analysed according to the Grounded Theory (Glaser & Strauss, 1998). The professionals were selected on their expertise in online education and/or ICT/sustainability. The professionals with expertise on ICT/sustainability were chosen because of their knowledge, insights, contribution and implementation of institutional policy of ICT, mobility and sustainability and their knowledge of the institutional policy towards online education. The professionals with a focus on online education are familiar with the possibilities and developments of online education in Dutch HE. The professionals were interviewed on the following topics: on the policy of ICT, mobility and sustainability, on why and to what extent and in what phase of the study online education is implemented; what impact online education has on study results; and what technological, pedagogical and organisational issues are coupled with the implementation of online education. They were asked whether the relation between online education and sustainability is recognized in the institution, especially the use of online delivery to reduce the travelling of students and staff.

The interviews (approximately one hour per participant) were held in March 2015. This type of interviewing gives the interviewees the opportunity to express their opinions and experiences

with regard to a new area of study — the relationship between carbon emissions, mobility and online education. All nine interviews were transcribed. A qualitative, interpretivist approach to content analysis is used. As stated earlier, the interviews are analysed according to the Grounded Theory, via a series of coding processes (open, axial) using the computer program Atlas.ti. Selective coding has resulted in the categories: DLE, Staff development, Commitment of students, and Interaction. The pros and cons presented in Table 2.4 are derived from citations of the professionals.

In May 2015, an expert meeting (three hours) with eight experts, invited by SURF, was held, where the results were presented and critically discussed. These experts were all different persons from the interviewed professionals (zero overlaps). The results reported from the interviews were confirmed during this meeting and thus the expert meeting served to corroborate the findings from the interviews.

2.4 Results

Scope 3 carbon emissions at Dutch HEIs

In this section, we present the travel-related emission data of the selected HEIs (Jonkers, Schwarz, & van Ewijk, 2015; Spapens, 2015; Tang, 2013), which calculated their carbon footprint according to the GHG Protocol. In Table 2.3 we show percentages of Scope 3 carbon emissions (student and staff travel). As stated before, the reliability of the data is not always the same and in some cases, system boundaries are not completely clear (Utrecht UAS, Utrecht University, Rotterdam UAS). The values concerning student and staff travel (third column) may also include business travel. As can be seen from Table 2.3, the relative contribution of student commute is much higher than that of staff. Given the ratio between staff and students — for example for Avans UAS (in 2015) the ratio is 1:10 (staff about 3000, students about 29 000) — this is a result that one would expect.

The GHG protocol reports from these HEIs show Scope 3 emission percentages relative to other emission sources. One should be aware that if the absolute carbon emissions are low (e.g. in case of the use of renewable energy) the percentage of Scope 3 emissions will be higher. As can be seen in Table 2.3, the Scope 3 emissions related to travel range from 40 per cent (University Utrecht) to 91 per cent (UAS Utrecht). In order to compare the Dutch GHG emissions with emissions from other countries (Section 'Carbon emissions due to student travel'), the absolute GHG emissions per person of the University of Amsterdam (UvA) and the Amsterdam UAS (Jonkers et al., 2015) are included in Table 2.3. The student commute from other countries ranges from 300 (Ozawa-Meida et al., 2013) to 630 kg CO_2e (Caird et al., 2015) per student and staff commute around 750 kg CO_2e (Bailey & LaPoint, 2016; Ozawa-Meida et al., 2013) per employee. This means that the emissions are in the same order of magnitude,

across the countries from which we could gather data.

Table 2.3. Percentages of carbon footprint of HEIs attributed to Scope 3 emissions (student and staff travel) of an HEI in a specific year, calculated using the GHG protocol, as reported by HEIs. In the two columns at the right, the carbon emissions (CO2e emissions) for student and staff commute in kg per person per year, are shown.
-: not specified by HEIs.

Higher education-al institu-tion	Year	Student and staff travel (total) (% of carbon footprint HEI)	Student commute (% of carbon footprint HEI)	Staff commute (% of carbon footprint HEI)	Student commute (kg CO2e per student)	Staff commute (kg CO2e per employee)
Utrecht UAS	2014	91	-	-	-	-
Utrecht University	2015	40	-	-	-	-
Amster-dam UAS	2014	81	71.7	4.4	630	540
University of Amster-dam	2014	58	35.4	8.1	340	410
Rotterdam UAS	2011	85	-	-	-	-
Erasmus University Rotterdam	2011	70	50	10	-	-

Notable is the high value of student commute of Amsterdam UAS (81 per cent, 630 kg CO2e per student). An explanation might be that UAS students mostly travel by public transport or car from the region to the city where they study (they stay at their parental home), whilst university students usually live on campus or otherwise use a bicycle to travel from the campus to their rental room in the city. A UAS sustainability professional confirms this assumption:

> "*We also examined the modal split of our students and six per cent commutes with a car and the rest with public transport, which is slightly different from the university and the assumption is that students of the UAS often stay at home with their parents longer, because the travelling distance to the institution is smaller; there are more universities of applied sciences than universities. This is also the reason for university students to rent a room in the city, where they study. (...) university students travel less with a car.*"

Measures and difficulties to reduce Scope 3 travel-related emissions

In this section, the results of the interviews with professionals of ICT/sustainability are presented, regarding the difficulties they encountered trying to implement measures to

reduce Scope 3 travel-related emissions.
Almost all institutions signed the LTA (long-term agreement) covenant and therefore implemented energy-efficiency measures since 2005. The LTA reports mainly show measures which have an impact on Scope 1 and 2 carbon emissions (RVO, 2016a; RVO, 2016b). Up to now the objective (two per cent of energy reduction every year) has been achieved, but maintaining this pace will be difficult in future. A sustainability professional notes:

> "I*n the beginning, it was obviously simple: if you erect a new building, you suddenly make a huge step, the campus is connected to the heating network, it's easy, but now it is getting difficult. It's difficult, because LED lamps are already installed and there is already a sustainable building. The limit is reached at a certain point and then you enter the areas, where it is most difficult. (...) looking at the footprint of our institution, this is student travel."*

Most measures for reducing the carbon emissions caused by student travel, aim at making it easier for students to reach the institution by public transport. Only one professional of a specific UAS mentioned blended learning as a measure to decrease carbon emissions. However, according to the other professionals of ICT/sustainability, the policy of their HEIs aims at getting the student as often as possible to the institution. They state that the general opinion in their institution is that online education should be implemented as a supplement and not as a replacement; otherwise, it might be at the expense of the quality of education.

Student travel is considered difficult to change, whereas HEIs believe they can influence the commute of their staff. Staff commute represents only a small portion of the total carbon footprint of HEIs in Amsterdam and Rotterdam (Table 2.3). There are incentives to get the employee from the car to an (e)bicycle. A UAS professional mentioned:

> *"an employee can get a subsidy to purchase an electronic bike.(. . .) I have 3000 employees and approximately 10 employees have bought this bicycle, this is a drop in the ocean."*

In addition, the discouragement of car use through the introduction of paid parking is mentioned, but this is a delicate topic and meets much resistance. "*According to research it is most effective to induce paid parking together with incentives, but at the moment we don't get any applause in the organisation for this measure*": according to a sustainability professional. Reducing the commute of staff by telecommuting depends in most institutions on the approval of the superior or manager. In general, it is not stimulated: *"because when a student is in need of a teacher, he can Skype, but our preference is face-to-face contact to discuss something"*(said by a sustainability professional).
The results of the interviews with professionals of energy/ ICT/sustainability indicate that the participating HEIs take (minor) measures to reduce Scope 3 travel emissions. These measures

consist of trying to change the travel mode into a less carbon-intensive one. Measures to reduce student or staff travel through online education meet resistance in the institution due to the notion (or prejudice?) that regular face-to-face contact promotes the quality of learning.

Pros and cons of online education as a means of reducing carbon emissions

As stated earlier, one of the great advantages of online education is a substantial decrease in carbon emissions. However, this is not commonly known at Dutch HEIs (Perez Salgado, 2008) and, according to Jacobs (2013), Dutch HEIs seem hesitant to implement online education structurally. In order to investigate this aspect in more detail, interviews with professionals were held. The interviewees state that the majority of the courses delivered by their own institution are web-facilitated (see for the classification Table 2.2). The HEIs are experimenting with online and blended learning courses for reasons such as international cooperation, personalised education with large numbers of students, facilitating international students, and flexibility in the provision of units of study. The advantage that online course delivery can lead to a reduction of the carbon footprint was new to most of the interviewed online education professionals.

The interviewees did recognize other advantages and in addition, a number of concerns were mentioned about online course delivery. In Table 2.4, we present these in the form of pros and cons, ordered around the interaction of the student with the course content, lecturer and fellow students. This type of order is chosen because typically in online education digital communication devices are used to facilitate this interaction, instead of face-to-face delivery.

Interaction student-content

In the interaction of the student with the content (learning materials) it is essential that the student gets motivated to learn. The professionals recognize the dangers of the distractions of staying at home, but in particular, the online education professionals indicate that a balanced course design in combination with individual coaching and monitoring of the students' progress can keep these distractions away. They even state that it might lead to better learning results if one adapts the learning materials to the needs of the student. They stress the importance of a balanced course design with a careful combination of content, didactics and technology. That would align with Ally (2004) and Bliuc et al. (2007) who emphasize the necessity of redesigning the pedagogical approach.

Table 2.4. Pros and cons of online education with respect to digital interaction, as reported by the interviewees(professionals). Each pro has a con mentioned next to it.

Interaction	nr	Pros online education	Cons online education
Student-content	1	Challenging online (or blended) course design, which is a balanced combination of content, didactics and technology activates the student and leads to deep learning.	Non-committal behaviour of students, because of not being at the institution.
	2	Personalised education is possible by adapting the learning materials, coaching and monitoring the needs of the student.	A lack of discipline and self-dependence leads to underachievement in online education.
	3	Digital Learning Environment (DLE) and digital tools provide the means to practise a presentation multiple times and discuss the result on a forum with or without the lecturer present, time-independently.	Ineffectiveness of online communication to learn, social skills, such as presenting and discussion.
Student - lecturer	4	The lecturer becomes a moderator, activating the student instead of giving a lecture.	Less flexibility. Online interaction does not provide the means to react immediately to signals of misunderstanding and misconceptions of students.
	5	The best lecturers are online available to give a lecture.	Less positive influence on students' learning through the presence of a lecturer, teaching face-to-face
	6	Online technology provides the means to structure the learning materials and to monitor the progress of the student.	A lack of face-to-face supervision of first-years can lead to underachievement.
Student-student	7	In a collaborative learning community students can interact with each other face-to-face as well as virtually.	Deterioration of collaboration and informal learning by not/less seeing other students face-to-face.

Interaction student-lecturer

The online education professionals see minor advantages of the lecturer in the role of teaching in front of the class. According to them, the lecturer should be someone who structures the learning materials, monitors the progress, activates the student by asking the appropriate questions, and explains the content if necessary. They state that in the first year of the study, the proportion between online and face-to-face contacts should be in favour of face-to-

face contacts, gradually changing towards more online education when progressing in the educational program. As can be seen in Table 2.4 the student-lecturer interaction changes in an online environment, therefore staff training and development seem to be a crucial step in the development of online or blended education. The scientific works on quality enhancement of e-learning seem to confirm this (Marshall, 2012; Ossiannilsson et al., 2012).

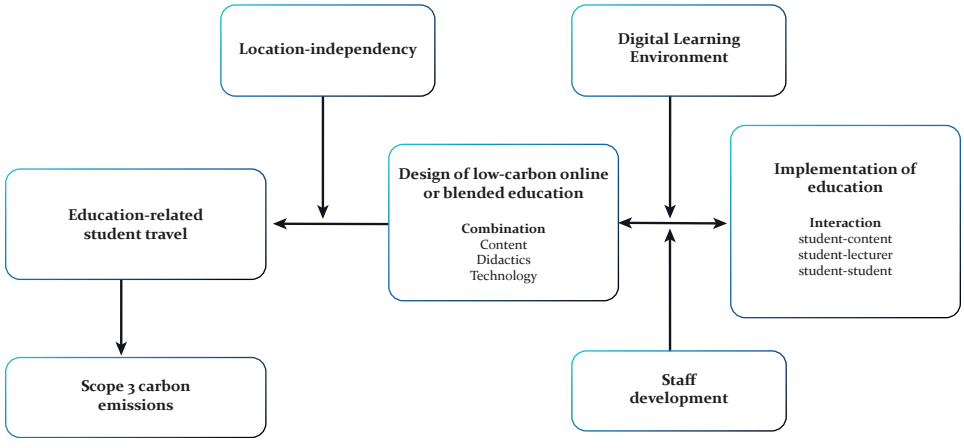
Interaction student–student

As for the interaction with fellow students, according to the professionals, this preferably takes place within a collaborative learning community, in which face-to-face contact is extended with online communication supported by a DLE. These comments are in line with Garrison and Vaughan (2008), who created a framework of a community of inquiry "to guide the research and practice of online learning" (p. 20). Regardless of which interaction is meant the professionals emphasize the importance of the DLE:

> *"We like to work with a powerful and characteristic learning environment, wherein the digital learning environment is an obvious part, which organizes the learning process and facilitates co-learning and co-teaching."*

The main aspects are visualized in a conceptual model, presented in Figure 2.1. Education-related student travel has an impact on Scope 3 carbon emissions. It can be lowered by incorporating location independency in the design of online education. Online education should be properly designed and be accompanied by a good DLE and proper staff development.

Figure 2.1. Conceptual model visualizing the relationships between online (or low carbon blended) education and Scope 3 carbon emissions



2.5 Summary and conclusions

This study reports an analysis of the contribution of student (and staff) travel to the carbon emissions of Dutch higher education institutions (HEIs), measured according to the Greenhouse Gas Protocol (Jonkers et al., 2015; Spapens, 2015; Tang, 2013). The contribution of these so-called Scope 3 travel-related emissions is between 40 and 90 per cent at the Dutch HEIs that were investigated. The scarce data reported from other countries (USA, UK) also show that the contribution of student travel is (very) high in the total emissions of an HEI. A comparison in detail is precarious, due to disputable data- quality (Bailey & LaPoint, 2016; Klein-Banai & Theis, 2013; Ozawa-Meida et al., 2013; Townsend & Barrett, 2015) and to national differences in travel behaviour and provisions of student housing facilities. Nevertheless, measurements in absolute values (CO_2e kg per student in a specific year) show that commute emissions per student in the US and UK are approximately in the same range as in the Netherlands, namely between 300 and 550 kg CO_2e. When considering options to decrease carbon emissions due to travel, HEIs try to influence the travel mode of students and staff towards less carbon-intensive travel modes (Hancock & Nuttman, 2014; Hopkins et al., 2016; Whalen et al., 2013; Zhou, J. P., 2012). In the Netherlands, a great number of students travel by public transport due to the fact they receive a free travel permit from the government. In both Australia and USA, the use of cars is much higher.

Furthermore, this study identifies the pros and cons of introducing online education in Dutch HE as a means of reducing travel-related emissions. The introduction of online education allows to achieve a huge reduction in carbon emissions and could thus help HEIs to achieve their energy efficiency and sustainability goals. We examined opinions of a carefully selected group of professionals at HEIs in de field of ICT/sustainability and online education. We analysed the interviews by applying grounded theory analysis. The professionals do not consider online education the most obvious measure to reduce travel carbon emissions, because they expect to meet resistance in their organisation, and they suspect it might deteriorate the quality of education. Measures are mostly sought in improving the accessibility of the institution to public transport, which in general is a lower carbon-intensive travel mode. Most online education professionals mention as a pro of online education the opportunity to personalise education to the students' needs and to extend the learning environment with digital media. As a con, they express their concern about the non-committal behaviour of students staying at home and deteriorated social processes between student and lecturer or fellow students. In order to meet the concerns mentioned, one of the directions to look into might be low-carbon blended education, since this also decreases carbon emissions, but retains some of the advantages of face-to-face education. Further research is needed to investigate the relation between the design of both online and blended courses and their carbon emissions. In order to successfully implement online education (or low-carbon blended education) as a means

to reduce carbon emissions the introduction and use of the DLE and staff development are considered important factors, just as the design and implementation of the courses, which influence the amount of location-independency of the education, and thus have an impact on the student travel. Implementing online or low-carbon blended education will have high implications for many stakeholders in HE. It demands leadership of professionals, technical and pedagogical support of service departments, development of lecturers, adapted design of curricula and an active learning attitude of students.

Future research will aim at investigating in more detail Scope 3 carbon emissions (also their absolute emissions, and not only their relative contribution) and at obtaining information for policy changes towards online (and low carbon blended) learning designs at several Dutch HEIs (at several levels: policymakers, professionals). An additional benefit might be an increase in awareness that student and staff travel in HE contribute substantially to carbon emissions.

Acknowledgements

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CHAPTER 3 Exploring sustainable student travel behaviour: balancing online and on-campus learning

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Abstract

Daily commuting trips of higher education (HE) students account for a large proportion of the carbon footprint of a HE institution. Considerations of students underlying their choice of travel mode and their decision to make the trip to campus or to study online are explored as a necessary first step for finding an optimal balance between online and on-campus learning from both a sustainability and an educational perspective.

Focus group conversations were held with student groups from different study programmes at a University of Applied Sciences in the Netherlands.

The findings show that Dutch students' travel mode choices seem to depend on measures regulating travel demand such as a free public transport card and high parking costs. The findings indicate that students make reasoned choices about making a trip to campus. These choices depend on considerations about their schedule, type, lecturer and content of a course, social norms, and their own perceived behavioural control. Alternative online options can provide students with more flexibility to make choices adapted to their needs.

This paper is one of the first studies looking at students' considerations when deciding whether to travel to campus to learn or stay at home learning online. While these findings are useful for sustainable and educational reasons, they also seem helpful in times of COVID-19 which calls for a re-design of curricula to allow for blended forms of online and on-campus learning.

Keywords: student travel behaviour, online learning, on-campus learning, higher education, class attendance, carbon footprint

3.1 Introduction

Stimulating a shift to low-carbon travel modes is one of the recommendations of the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2014, p. 603) to countries for lowering their greenhouse gas (GHG) emissions. Many countries are looking for ways to lower their GHG emissions and are thus trying to meet the 1.5-degree target as set in the Paris Agreement (UN, 2015, chap. 21). According to the IPCC, transport is responsible for 23 per cent of global GHG emissions (in 2010) (IPCC, 2014). However, the IPCC also recommends: "avoiding journeys where possible" (IPCC, 2014, p. 603). This study focuses on students' journey from home to their educational institution, considering both IPPC recommendations.

Globally, many university students commute almost every day to their institution, contributing to GHG emissions and air pollution. Having an online learning alternative may decrease these travel movements. Information and Communication Technology provides educational institutions with capabilities to deliver a course (or part of a course) location independently, using the internet. An obvious requirement is that organising a study program that significantly reduces student travel should not compromise the quality of education. Making a conscious attempt to decrease travel movements is, as far as we know, in an educational context unexplored territory. In the few studies about student travel behaviour, a modal shift from car to alternative (lower-carbon) travel modes is the main topic of interest, especially in countries with a high car dependence like Canada (Whalen et al., 2013), the United States (Zhou, J. P., 2012), and Australia (Hancock & Nuttman, 2014).

The significant environmental impact of student travel becomes clear by looking at the carbon footprint of higher educational institutions (HEIs). The carbon footprint is an indicator of the magnitude of GHG emissions caused by activities of an individual, a group, or an organisation (WBCSD, 2014). Many universities and colleges worldwide are looking for ways to reduce their carbon footprint as one response to what is increasingly referred to as 'climate urgency' (UoE, 2019). Studies about the carbon footprint of an HEI are rare (Li, Z. et al., 2021), and only some of these studies include student travel in their measurements. The reported estimations of the annual carbon emissions due to students' commuting vary between 300 and 630 kg CO_2e per student in countries, such as the United Kingdom (Caird et al., 2015; Ozawa-Meida et al., 2013), the United States (Bailey & LaPoint, 2016), and the Netherlands (Versteijlen, Salgado, Groesbeek, & Counotte, 2017). While most universities consider travel-related emissions as a significant part of their carbon footprint, they tend to focus on (long-distance) travel of staff to international meetings and conferences, often by plane, ignoring the much more frequent local commute-related student travel (Hopkins et al., 2016; Versteijlen et al., 2017).

Besides environmental considerations, a natural disaster or crisis may be another reason for HEIs to restrict student travel temporarily. During the COVID-19 pandemic, the most frequent initial response of higher education in countries categorised as developed economies was to

close campuses, followed by an immediate transition from on-campus to an online learning environment to support students to continue with their studies (Crawford et al., 2020). This rapid movement to digital education has exposed deficiencies in existing infrastructure, pedagogic knowledge and teachers' experience (Ali, 2020). Higher education needs to improve the resilience of their academic programs to be prepared for unanticipated interruptions (Ali, 2020; Mackey, Gilmore, Dabner, Breeze, & Buckley, 2012). This first exploration, aiming at reducing student travel by location-independent learning using the internet, can be helpful.
This paper presents the results of a study on travel behaviour of Dutch students. The Netherlands distinguishes itself from other countries through a combination of high population density, a high-quality infrastructure (for travelling by car, bicycle and public transport) and a strong cycling culture (Belgiawan et al., 2014). In the Netherlands, approximately 75 % of the student trips to campus are done with a low-carbon travel mode, that is, public transport (ca. 50 %) or bicycle (ca. 25 %) (CBS, 2016). This is partly due to the characteristics mentioned above and other factors, which will be discussed in the subsequent sections. Because most Dutch students seem to make a sustainable travel mode choice, more sustainable gain could be obtained from decreasing the number of trips to campus. Dutch students travel on average 45 minutes on a weekday for educational purposes (CBS, 2016). Therefore, in this study, the emphasis lies on the potential of (online) learning activities to mitigate the number of student trips to campus. In addition, lessons may be learned from the Dutch approach to stimulate students to choose a low-carbon travel mode.
To make a study program possible that mitigates education-related student travel emissions as well as maintains, or ideally improves, study quality, the first crucial step needed, and aim of this study, is to explore students' considerations and (de)motivators influencing their travel mode choices and their decisions whether to travel to their institution or to study (online) from home or a place that does not require travelling. In addition, account is taken of the possibility that studying at home stimulates a student to increase travelling to non-study activities. Hence, measuring travel emissions needs to consider the direct as well as the indirect effects of studying at home. Therefore, if 'education-related student travel' is mentioned, we refer to all (direct and indirect) domestic student travel due to their education. We limit ourselves to regular full-time students, who represent the majority in higher education.

The education-related travel behaviour of Dutch higher education students is explored based on two research questions:

1. What are the perceptions, attitudes and, preferences of students involved in the process of choosing
   - a particular travel mode to commute to campus?
   - to make a trip to campus to attend learning activities?
2. From a student's perspective, to what extent could substituting in-class meetings with online learning be an appropriate measure for reducing their travelling?

Based on a literature review, we will first provide a theoretical background on factors influencing students' travel behaviour, which converges into a conceptual model. We will then introduce the methodology and methods used to answer the two research questions. The presentation of the findings makes up the central part of the paper to end with a discussion and a conclusion.

3.2 Reviewing theory about students' travel choices

Higher education students are in many aspects, but certainly not all, socio-economically speaking, a homogeneous group with similar characteristics. Students are generally unmarried, have no children, have a lower (or even no) income and are younger of age (Zhou, J. P., 2012). Travel behaviour research is usually aimed at understanding people's travel behaviour in general in order to support the development of effective transport policies (van Wee, Annema, & Banister, 2013). The next sections discuss to what extent theoretical concepts from travel behaviour research can be applied to student travel behaviour.

Hierarchical decision structure

The concept of a hierarchical decision structure (Salomon & Ben-Akiva, 1983; Van Acker, Van Wee, & Witlox, 2010) is useful for understanding how the differences with the general population might influence students' travel behaviour. This hierarchical decision structure distinguishes long-term, medium-term and short-term decisions of individuals. Long-term decisions are, for instance, decisions on lifestyle. Lifestyle is defined as "the pattern of behaviour which conforms to the individual's orientation toward the three major roles of a household member, a worker and a consumer of leisure, and which conforms to the resources available" (Salomon & Ben-Akiva, 1983, p. 624). Medium-term decisions, such as location choices in relation to study/work, are made in conjunction with the adopted lifestyle (Van Acker et al., 2010). Short-term decisions on daily activities and travel are expressions of behaviour determined by lifestyle and the associated locational choices (Van Acker et al., 2010).

Applying the hierarchical decision structure to education-related student travel, long-term decisions, such as, whether to adopt a family-oriented (living with parents) or an independent lifestyle is, besides academic reputation of the HEI, an important determinant for the medium-term decision in choosing a university (Briggs, 2006). The choice of location, where to live or study, influences the travel mode, the distance to campus and probably even the number of trips. In most cases, students who continue to live in their family home will have to travel to campus by public or motorised transport. In contrast, students who live independently relatively close to the campus can often cycle or walk. One of the topics of this study is whether a longer travel time affects the motivation of students to attend learning activities on campus, thus affecting the number of trips.

Although the long-term and medium-term choices of students affect regular students' daily activities and travel behaviour, it will be considered out of scope for this study.

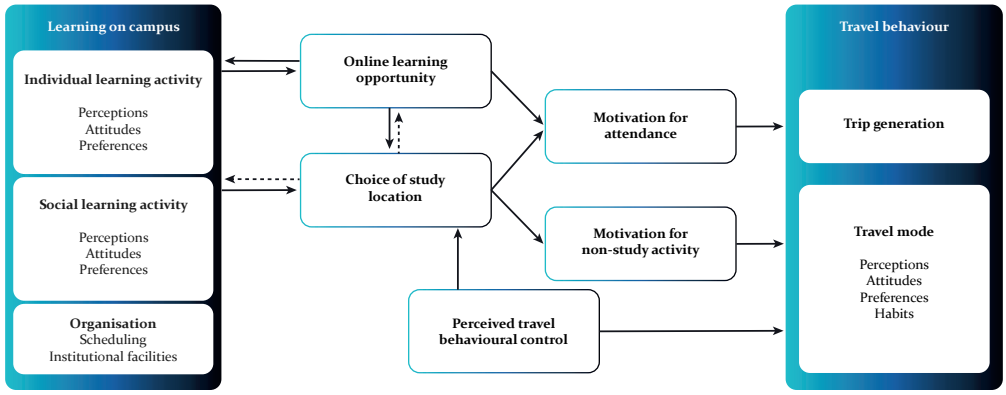
Education-related travel behaviour choices

Studying full-time in higher education allows students to have control over their study schedule. Daily, students have to decide if they will attend an on-campus learning activity and how to commute. In travel behaviour research, an individual travel behaviour decision is often considered from an economic, geographical and psychological perspective (Van Acker et al., 2010; van Wee et al., 2013). From an economic viewpoint, an individual is considered a rational human being making consistent and efficient choices that maximise its utility (Avineri, 2012). Time geography describes the path of an individual through time and across space in which activities require joining with others at a certain time and location as well as accessibility of destinations (Hägerstrand, 1970). From a psychological perspective, an influential theory is the Theory of Planned Behaviour (TPB) (Ajzen, 1991). According to this theory, individual behaviour results from an intention dependent on attitude, social norms, and perceived behavioural control. Attitude refers to how a person evaluates or appraises a particular behaviour. Social norms refer to the perceived social pressure and perceived behavioural control to the perceived capability of performing the behaviour (Ajzen, 1991). TPB assumes that behaviour results from a reasoned choice, and this assumption does not always apply. Within a static situation, a behavioural choice can respond to past experiences and can result in an automated reaction (Gardner, 2009; Verplanken & Aarts, 1999). Applying this to student travel behaviour, an initially chosen travel mode by students will become a habit (Haggar, Whitmarsh, & Skippon, 2019) in contrast to the (probably) reasoned choice of a student to travel to campus to attend learning activities. In two studies about students' attendance decisions, the TPB framework nevertheless proved to be an accurate model to explain the intention and behaviour to attend a lecture on-campus (Ajzen & Madden, 1986; Hollett, Gignac, Milligan, & Chang, 2020). These studies found perceived behavioural control to be the strongest predictor of this attendance decision. However, the effect of having the opportunity of watching an online lecture is not considered in these studies. Unlike the NOA model, which shows that behavioural choice is affected by needs (N), opportunities (O) and abilities (A) of a person (van Wee et al., 2013, chap. 3), the standard conceptualisation of TPB does not explicitly include alternative choice options.

In this study, the focus lies on the short-term behavioural travel choices of individual students. Following the theoretical psychological concepts, depicted in Travel for Learning (Figure 3.1), a student's travel behaviour probably stems from a motivation to attend learning activities on campus. This motivation, or in TPB terms, 'intention', may depend on their evaluation of the actual learning activity. This can be an individual learning activity, like a lecture, practice or self-study or a social learning activity like collaboration. In their evaluation, students' perceived study abilities probably were taken into consideration. In addition, contextual factors, e.g. scheduling issues, may influence their decision to attend (Moores, Birdi, &

Higson, 2019). The choice of where to study may also be affected by a student's evaluation of travel constraints, such as distance and duration of travel and travel costs. Substitution of on-campus learning activities with online learning will provide students with an opportunity to study location independently and may affect the need to travel to campus. Moreover, it may have an indirect effect because being at home may affect student travel through an increased motivation for non-study activities.

Figure 3.1. Initial conceptual model: Travel for Learning. Based on: conceptual model of travel behaviour (Van Acker, Van Wee, & Witlox, 2010), NOA model (van Wee et al., 2013, chap. 3) 3), Theory of Planned Behaviour (Ajzen, 1991). Dotted arrows refer to feedback mechanisms as a result of learning from experiences.



3.3 Methodology

Dutch students' travel mode choices and commuting in relation to the received education is a relatively unexplored territory. Therefore, we used an explorative methodology, that is, focus group discussions, to better understand the complexity surrounding students' preferences and attitudes towards their travel behaviour. We opted for focus groups because a group of students interacting with each other about their views can provide insight into their thoughts and beliefs, especially in more homogenous groups with a high level of trust (Clifton & Handy, 2003; Stewart & Shamdasani, 2014). Nevertheless, there may be a danger of "'contaminating' social influences such as conformity and social desirability", especially for groups that focus on sensitive topics (Hollander, 2004,p. 610). In our focus groups, the topic of discussion is not sensitive for the students. Some of the precautions we took to reduce 'contaminating' social influences will be discussed in the subsequent sections.

Context

We conducted our research in 2019 during March-May at Avans University of Applied Sciences (Avans UAS). Avans UAS has a wide range of bachelor studies and a large number of students (26,725 full-time students, 09-10-2018) divided over four cities (Den Bosch, Tilburg, Breda,

Roosendaal), thus providing the opportunity to select students from various bachelor studies and different study cities. We have chosen a UAS because, compared to university students, a larger number of UAS students commute by car or public transport to their educational institution (Versteijlen et al., 2017).

Two Travel Demand Management (TDM) measures, that is, strategies to change travel behaviour, influence the travel mode choice of the Dutch participants. First, in the Netherlands, all higher education students receive a free public transport permit and second, Avans UAS does not facilitate parking of cars for students. Students can park their car in a parking garage, paying an hourly rate, or can try to find free parking space in the neighbourhood of the institution (which is difficult).

Participants of the focus groups

Student recruitment was done by a notification on their digital learning environment followed by an appeal during an in-class session. As compensation for their efforts, we offered them lunch during the session or minimum hourly wages.

Five focus groups were organised with 28 full-time students (12 female, 16 male). A senior student may easily overrule a student with less experience, so the participants were divided according to their study phase. Two focus groups (FG2, FG3) contained 11 first and second-year students and three focus groups (FG1, FG4, FG5) 17 third and fourth-year students. The bachelor studies involved (number of students in brackets) are Informatics (8), Communication & Multimedia Design (1), Business Administration (2), Finance and Control (2), Accountancy (4), Social Work (7), Civil Engineering (2) and Building Engineering (2). Regarding the participants' travel distance, four participants live in the neighbourhood of the campus and can cycle or walk. Twenty-four participants have a travel time of approximately between 20 and 120 minutes with public transport. Four of the participants study in Breda, two in Tilburg, seventeen in Den Bosch and seven on the eastern side of Den Bosch.

Moderator and interview guide

The focus groups were led by a moderator experienced in sustainable transport policy with no relationship with the students. The main researcher (first author) observed all focus group meetings while notes, and audio and video recordings were made.

The topic of discussion was introduced to the participants beforehand by mail. At the beginning of the sessions, they were assured that all their statements were to be treated confidentially. Subsequently, they were asked to fill in a consent form and to provide some personal data: name, year of birth, gender, place of residence, place of study, bachelor study, study year and commuting information with regards to travel modes and the number of trip generations per week (over the previous three weeks). In order to have an individual starting point and prevent group bias we asked them to draw their preferred way of travelling to the institution (in green) and the less preferred alternatives (in red) on a pre-printed A3 sheet (Appendix: fig. A1, Fig. A2). We provided some icons students could use to make drawing a little easier (Appendix: fig.

A3). In addition, we asked them to use stars to indicate the likelihood of coming to campus for particular learning activities:

* I never come to campus for this
** I sometimes come to campus for this
*** I often come to campus for this
**** I always come to campus for this

The interview guide contained all the questions and some clues about what can be expected of the student's answer. The sessions lasted on average 1.5 hours. The complete planning of topics of discussion during the session is depicted in Table 3.1.

Table 3.1. Planning of the session

Topic of discussion	Time (minutes)
Introduction	5
Travel drawing creation	15
Travel mode	20
Attendance learning activities: lecture, practice, self-study, collaboration. Online learning substitution.	30
Other aspects: social contact, social norms, course schedule, environment	10
Travelling to non-study activities in relation to educational design	5

Data analysis

The recordings were all transcribed and anonymised. Every participant can be identified with a code containing:
FG[number of focus group]_[gender (M/F)][number of participant]
All drawings and personal data were digitised. All transcriptions were analysed using Atlas.ti qualitative analysis software (version 8), taking the following steps:

1. *Scissor-and-sort method (Stewart and Shamdasani, 2014).*
   The first step was to go through all the transcripts, identify fragments of text relevant to the research questions, and give these fragments a code. This resulted in 81 codes. Examples of codes are: "Acquisition online-f2f" or "Appreciation online lecture". A set of sorted materials was yielded by categorising the codes into code groups. The defined code groups are: acquisition, practice, self-study, collaboration, student, lecturer, course schedule, online communication, travel mode and travel issue.

2. *Focus group coding*
A personal profile of each participant was created by combining personal data, data from drawings and their paraphrased quotations (ordered according to the code groups, using step 1). It provided the possibility to analyse the interdependencies of the personal data of the participants and their opinions.

3. *Collecting constraints and motivators of travel mode and trip generation*
The profile of step two was used to collect, in keywords, all constraints and motivators stated by the participants about travel mode and trip generation (translated into English and depicted in tables). An example of a table item can be seen in Table 3.2.

Table 3.2. Constraints and motivators uttered by participants about public transport. Number in brackets is the frequency

Subject		**Consideration**
Public transport use	Constraint	Unreliable (3), crowding (4), unpredictable (2), transfer, delay, long travel time, accessibility.
	Motivator	Environment, convenient, travel to city (2), short travel time (2), reliable, other activities during travel (4), no costs (5), personal chauffeur, bad weather conditions.

4. *Defining attitudes and collecting associated perceptions towards travel mode and trip generation.*
With the information from the preceding steps, the attitudes and associated perceptions of the participants were distilled. These attitudes and perceptions were translated into English and depicted in a table. An example can be seen in Table 3.3.

Table 3.3. Example of attitude and perceptions about self-study

Attitude	**Perceptions**
At home, concentration is better	FG5_F2: I prefer studying at home. Because it is a large space here [campus], you hear everything and I am easily distracted.

3.4 Results

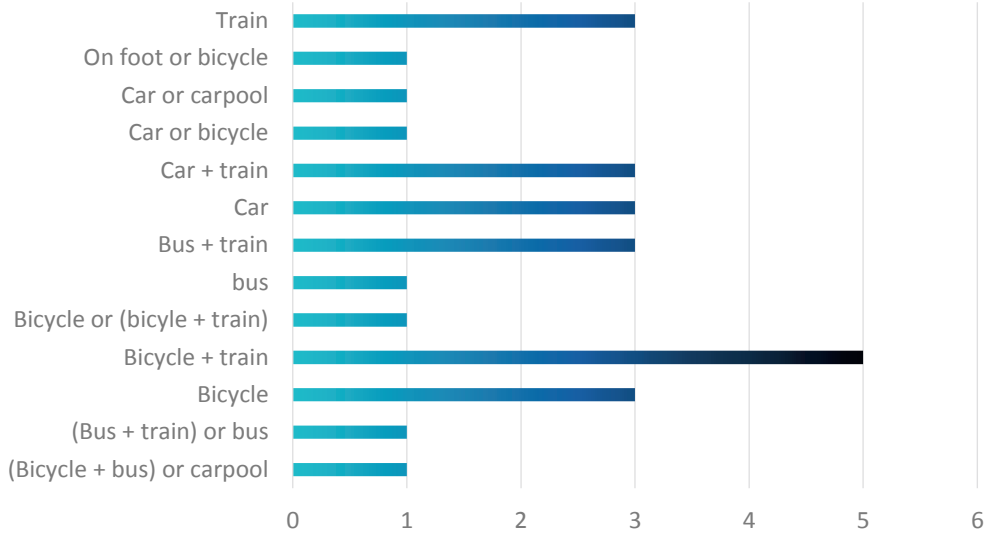
The focus groups offered rich information on all topics of discussion. As much as possible, the findings are presented according to the planning of the topics (Table 3.1). The attitude of students towards these topics is, in most cases, illustrated by quotes.

Student travel mode

In Figure 3.2, the preferred travel modes of the participants commuting to campus are depicted (from their drawings). Approximately half of the participants have access to a car by owning, sharing or borrowing.

Most participants consider public transport as the preferred mode of commuting (Figure 3.2). The attitudes and perceptions that underlie these preferences and the actual choices will be discussed in five themes: travel costs, travel time and reliability, travel convenience and environmental considerations.

Figure 3.2. Count of preferred travel modes of participants (from the drawings)



Travel costs

Students tend to have a low income, so travel costs are an important issue when choosing a travel mode.

> *"We travel with public transport free of charge, I mean, you guys, too, with our student travel permit, you're crazy if you don't use it"* (FG5_M2).

The participants frequently mention the high cost of travelling by car. Especially, having to

pay parking costs is a reason for not taking the car. It was the main reason for two participants to switch from car to public transport for commuting to campus. Occasionally, this is dealt with by taking the car only for short campus visits, as this reduces the costs of parking.

> *"So, what I really look at is: will it cost me money and does it take too much time. Because I want to be there as soon as possible so that I can be productive. If it takes me too long, I will grab the car and park it as close to campus. Often, in case of short visits or just having a meeting and then I'll be gone again immediately. So, if I have to be there all day, I never take the car"* (FG5_F1).

Travel time and reliability

Travel time seems less of an issue for the participants than costs. However, one participant who had a total travel time of four hours to attend class eventually chooses to move: *"I didn't really plan to move. I thought: oh, I'll hang on, but it's really not doable"* (FG3_F3). So, there seems to be a limit to an acceptable travel time. Another participant finds a solution in combining car and public transport to optimise travel time and travel costs.

To be on time for an exam is when the travel mode needs to be reliable. There is no consensus on which strategy works best. All students leave early, but some take the train and others the car to be on time.

Travel convenience

The convenience of travel definitely plays a role in choosing a travel mode by the participants. Some like to travel by public transport because they can perform other activities during their travel time.

> *"I like it pretty much. (...) I'm always on that train and if I have to do: things for school, for example learning or programming"* (FG2_M4).

Others value the freedom of choice to have a detour option to go to other activities after their on-campus attendance. A participant states about using a car:

> *"Always a place to sit. After college, I have a lot of activities and I have the freedom, taking little time, to go to other places immediately instead of going home first"* (FG1_M6).

Needing storage space or dealing with bad weather conditions are also mentioned as reasons to adapt their travel mode to a car.

Carpooling and cycling

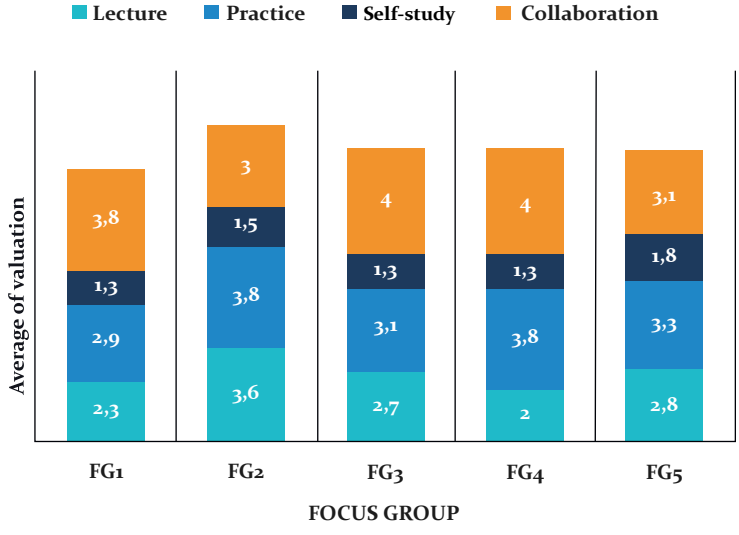
Only one participant mentioned carpooling as a serious option for commuting. Most participants found it challenging to organise having few or no fellow students in the

neighbourhood, and when they did, these students would usually have a different class schedule. Having an excursion is mentioned several times as an occasion for carpooling.
Most participants started to laugh when we mentioned the possibility of using an e-bike. They agree on the fact that using an e-bike is more for elderly people. Some participants emphasise the active and relaxing value of cycling.

Environmental considerations
Most participants agree that choosing a travel mode has to do with costs and time rather than environmental considerations. Only two participants mentioned the environment as a reason to travel by public transport.

Trip generation: attending learning activities
On average, the participants commute approximately four times a week to campus. They commute because they are supposed, but not obliged, to attend a learning activity. Figure 3.3 shows the average of valuation which indicate how the participants evaluated the various learning activities at the beginning of the focus group meeting (explained in section 3.3). These averages have to be considered only as a first indication.

Figure 3.3. Average of valuation (1-4) of the learning activities by the participants per focus group



The attitudes and perceptions that underlie these participants' valuations (Figure 3.3) and the online equivalent (except for self-study) will be discussed per learning activity. The participants had varying experiences with online learning, so we provided them with implementation examples. In addition, some general subjects will be discussed: peer pressure, socialising with peers, and course scheduling.

Lecture

During a lecture, the lecturer conveys theoretical concepts, often supported by a digital presentation of slides, in front of an audience that may amount to 100 or more students. Usually, there is little interaction between the lecturer and the students.

Having a lecture as the only learning activity on a day is, in most cases, not enough reason for the participants to commute to campus:

> *"My attention span isn't long enough for a lecture (...), but if I have to come to school or stay at school especially, then I'm like: No, I'm not going to travel for three hours in total to attend. And I even don't learn much"* (FG3_F1).

Concentration loss during a lecture is a recurring theme among the participants. Still, most participants are convinced that knowledge transfer by a lecturer is a necessity, but the way it is done in a lecture is a point of discussion. Some participants experience a lecture as useful for learning:

> *"I learn the most from these lectures because when something is explained to me, in most cases, I understand immediately what is said. It is not necessary to study this at home once again" (FG2_M4).*

> *"I like that everyone is doing the same thing. In one way or another, it gives me more focus "*(FG5_M1).

The participants state that they can be motivated to attend a lecture by having other learning activities on the same day, an inspiring lecturer and difficulty/usefulness of the subject. Demotivating for attendance is: not being missed, prior knowledge, no time to ask questions, or other opportunities to acquire the concepts discussed in the lecture.

Online lecture

What if a lecture has been recorded on video and made available on a digital learning platform? "Then it will be a very deserted campus [laughter]" was the first reaction to this question in FG1. On the whole, there was consensus among the participants about the usefulness of online registration of a lecture. FG3_F3 states:

> *"Sometimes you don't understand a sentence or something and you don't want to ask for an explanation in a full lecture hall. At home you can rewind the recording".*

Other advantages mentioned are: watching anytime, anywhere (even while travelling), more time for making notes, refreshing knowledge before exams. Nonetheless, some participants favour attending a live lecture:

> "*Being there live, you experience it much better than when you see it on video. Personally, I learn a lot more by attending a lecture than watching a vide registration of a lecture*" (FG2_M2).

Learning by practice

During a practice class, an individual student applies his/her understanding of the theoretical concepts by completing an assignment, prepared and supervised by a lecturer. The organisation depends on the study: in economics and informatics, a practice class is a mix of theory and assignments. Technical studies need all kinds of technical facilities, and in social studies students need each other to practice communication skills. A practice class contains approximately 16 to 32 students, and usually, attendance is required.

Attendance in a practice class cannot be taken for granted. Especially if it is the only learning activity during a day, the participants consider the usefulness and necessity of attending. They value the interaction with the lecturer and fellow students during the practice class:

> *"(…) doing assignments and if you don't get it, you can ask immediately (…) and you hear feedback of fellow students about how they made their assignment"* (FG2_M3).

Getting feedback on an assignment is mentioned quite often as being important:

> *"(…) if I don't go, I feel insecure about the quality of my work. I won't have the possibility to double-check if everything is in order"* (FG1_F1).

Still, one of the participants states:

> *"I'd rather have a specific block of time, let's say, eight hours, working on some subject at home, and learning a lot, instead of every week one hour here and one hour there on campus"* (FG1_M1).

A lecturer will probably notice whether or not a student is present. So, although it may not be obligatory, the participants feel occasionally obliged to go, because they do not want to offend the lecturer.

Online learning by practice

What if you do your assignments online supported by a digital learning environment that facilitates interaction with the lecturer and fellow students?

For participants of social studies or civil engineering, this seems out of the question because students of social studies need each other to practice social skills while students of civil engineering need facilities: *"I have no [water] basin of 20 cubic meters at home"* (FG5_M1).

However, they see potential in online materials which can prepare them for practice class. Another influencing factor is having face-to-face interaction with fellow students:

> *"It is like when you compare your assignment with someone else, you look deeper into why you did what you did and why he did what he did (...) and online: many times you get the inclination already to type something before the other person finished to make his point"* (FG2_M3).

Some participants already experienced and appreciated what feedback online might entail in the form of Frequently Asked Questions (FAQ) online or a screencast with which they can check their assignment elaboration.

Self-study

Self-study is location-independent learning of theoretical concepts or completing assignments without the supervision of a lecturer. A student may study at home, in the library of the UAS or some other study location in the neighbourhood of his/her residence.

There is no consensus about the best place to study among the participants, at home or on campus. Next to travel time, getting distracted is the main consideration when choosing a proper location for self-study. Some participants get distracted at home: *"(...) on campus I am not tempted to play a computer game or something like that"* (FG2_M2). Others complain about the surrounding noise of other students when studying on campus:

"I like to study at home, nice and quiet" (FG4_F1).

Travel time is an issue when considering whether or not to go to campus for studying:

> *"I am not going to campus for this, no, that really provides no added value for me (...) and often, after travelling by bus, you arrive tired"* (FG5_M1).

Most participants agree that they do not need face-to-face contact to get answers to questions from fellow students. They use WhatsApp or a phone call to communicate with their fellow students.

Collaboration

For collaborative learning, a group is formed of four to eight students. They have to construct something, which is necessarily done through participation and negotiation with fellow students (Laurillard, 2013).

The participants agree that collaborating to make an assignment needs a physical gathering at least once a week. They mention the UAS as a central and neutral meeting point. For some participants, the main reason for gathering is organising the work.

> *"What I like is meeting once a week with your project team on one or half a day, and the*

remaining tasks are distributed and carried out at home " (FG1_M3).

In addition, the physical meeting is experienced as productive and motivating. Social control is also mentioned as a motivator.

Online collaboration
The participants did not have much experience with digital environments that support online collaboration. They mention WhatsApp, Skype and Discord as tools for digital communication. These tools are better suited for one-to-one communication. The following narrative illustrates what can happen if you only communicate using WhatsApp:

"At a certain moment, we had to make a film, and we had to hand it in on Monday after the Christmas holidays. Well, of course, no one wanted to meet during the Christmas holidays. Well, really, WhatsApp exploded. People got out of the group app and nobody wanted to communicate with each other anymore. It was just a big mess. That was caused by many misinterpretations via WhatsApp because you don't have someone's face in front of you and also, someone asks the same question for the 100000th time because no one has read the apps properly" (FG3_F3).

In addition, they mentioned distraction as a constraint to collaborating online:

"You're more distracted. You're on your computer. The Internet is just a few clicks away and before you know it, you're looking for something else" (FG4_M2).

Course schedule
Only a few participants, mainly first-year students, state that they always go when a lesson is scheduled. The reasons mentioned not to attend class, even if it is scheduled, are: only one class scheduled during a day or the scheduled class occurs after 15:30. A motivator to go to campus is having a fully scheduled day.

"That's what we've had in our first year. (...) You just have a lecture in the morning, then you can work all day on assignments, practice in groups or alone, and afterwards, you can ask questions and have a feedback moment with the teacher. I appreciated this system" (FG5_M1).

Peer pressure and socialising
Some participants experience peer pressure to attend classes:

"I also experience a bit of peer pressure because some students, they always go ... then you feel kind of bad if you have missed a few" (FG1_F3).

It may also go the other way around:

> *"If in the group's app someone says: I won't go to campus, half of the group members will not go either"* (FG3_F4).

Collaborating to do an assignment demands the engagement of all the group members and, as one participant mentioned, not only to participate in completing the assignment but also to attend supporting courses.
Collaborating in a group may also stimulate attendance for wanting to socialise with group members.

> *"I really like it on campus. I think it's a reason to go. I would find it very boring if I would only get education at home, (...) I also attend class because I just like my learning team."* (FG3_F5).

Still, there are also opposing opinions about this socialising aspect.

> "*for social contacts I don't go to campus [laughs] (...) I rather go to a pub. I'm just for myself and for my group mates on campus(...)"* (FG5_M1).

Trip generation: online learning in relation to travelling to non-study activities
The participants were asked how it would change their travel behaviour to non-study activities if part of the on-campus learning activities were substituted by online learning.
Most participants think that it would not increase their number of trips to non-study activities. Their non-study activities, e.g. meeting friends, often take place in the neighbourhood of their residence. They also think that the decision to go to an activity further away, for instance, going to a concert, is not influenced by spending a day on campus. Some think that it would change the moment when they plan non-study activities.

> "*Then my own time is easier to plan. Okay, this evening let's go crazy: we go to the theatre. Why? Because I have the time for it. I don't have to be at school early tomorrow. Yes, okay, I have to take my homework into account, but I also have a Saturday or a Sunday and the evenings"* (FG5_F2).

Still, it also depends on where you live and the availability of a car.

> *"I would certainly study [at home, online], but it's also: gosh, I'm going to get a cup of coffee at someone's place, or I'm going to the gym. (...) The village nearby that is already about 10 km. Then I grab the car and I drive to my friend and back"* (FG4_M2).

3.5 Discussion

Our objective was to gain insight into the considerations of higher education students choosing a travel mode and making a trip to campus as well as the potential effect of online learning on this travel behaviour. We will limit our discussion to the three key travel aspects covered in this research: travel mode choice, trip generation and travel to non-study activities. In addition, study limitations and recommendations for future research will be discussed.

Travel mode choice

Dutch students tend to choose low-carbon travel modes, that is, public transport or bicycle, to commute to campus (CBS, 2016) as is the case with our participants. Influencing factors mentioned include having a free public transport permit and high parking costs near the campus. Other influencing factors for choosing a travel mode include travel time, reliability and convenience. Environmental considerations were rarely mentioned. This latter observation corresponds with findings from a study conducted in the United Kingdom, in which more focus on students' awareness of sustainability-related issues in HE is advocated (Green, Morris, & Wade, 2012). Overall, the participant's choice of travel mode seems to be a habitual choice considering their individual drawings and commute information, confirming the findings of earlier studies (Gardner, 2009; Haggar et al., 2019). The habitual travel mode choice is reconsidered when a change in normal circumstances occurs, such as having an exam, only needing to be on campus for a short visit or bad weather conditions. Safety issues are not mentioned in our findings in contrast to studies from other countries (Maguire & Morris, 2018; Miralles-Guasch & Domene, 2010). This may be due to an adequate Dutch infrastructure regarding public transport or bicycle usage.

The potential effectiveness of travel-regulating measures (TDM) to change student travel mode choices is demonstrated by the value the students attribute to travel costs, also confirmed by other research (Whalen et al., 2013; Zhou, J. P., 2012). However, it should be noted that probably a combination of TDM measures, such as, in our case, a free public transport permit and high parking costs, is necessary to stimulate a change to a lower-carbon travel mode (Sultana, 2015). An additional long-term effect of encouraging students to opt for low-carbon transport systems is a possible negative impact on their intention to purchase a car after their studies (Muromachi, 2017).

Trip generation

The decision to make a trip to campus seems to be a reasoned choice and results from an intention to engage in a particular behaviour concerning class attendance. The preferences and attitudes of the participants stem from an evaluation of both the number and the time of the day of the scheduled classes and the kind of learning activity, as depicted in our initial

conceptual model (Figure 3.1). Their perceived study abilities are part of their evaluation of the learning activity. Examples in our findings of its influence are the ability to concentrate, the perceived complexity of theoretical concepts, and the need for feedback and answers to questions. With respect to the social environment, some participants mention pressure from peers and lecturers persuading them to attend. The kind of lecturer, required facilities and study area of the learning activity also seem to be influencing factors of attendance and can be categorised under 'Institutional facilities', next to scheduling. Regarding scheduling issues, Moores et al. (2019) concluded, after a review of studies exploring attendance in higher education, that the timing of scheduled classes probably is an issue for some students. Our findings confirm this conclusion. When having a single learning activity on a day, an activity late in the afternoon or, long gaps between activities, students often decide to skip these learning activities. Most students showed a positive attitude towards clustering learning on campus one or two days per week in the sessions. All these (de)motivating factors concerning learning on campus are weighed against the perceived behavioural control over travel constraints (e.g. costs, time and distance) and the opportunity to learn online instead.

The weight this online opportunity receives in the attendance decision is different for each type of learning activity. Learning activities like collaboration and practice are considered important to attend on campus. The participating students agreed that collaboration needs face-to-face contact on a regular basis. Practice classes on campus are valued because of the opportunity to get instant feedback or answers to questions from the lecturer and fellow students and practical reasons such as learning facilities only available on campus. Studying in the library or only having a lecture is usually not enough reason for the participants to make a sometimes long and tiring journey to campus. Their negative attitude regarding studying in the library contradicts the findings of Regalado and Smale (2015), which showed that commuter students from the City University of New York valued the library as a distraction-free place for academic work (Regalado & Smale, 2015). Most students were positive about knowledge acquisition by utilising online lectures. They valued the possibility to replay the explanation of theoretical concepts. The effectiveness of online lectures seems to depend on the students' perceived study abilities (Montrieux, Vangestel, Raes, Matthys, & Schellens, 2015; Von Konsky, Ivins, & Gribble, 2009). Alternative online options, like online lectures, can provide students with more flexibility to make reasoned choices adapted to their needs.

Travel to non-study activities

Limiting on-campus learning to one or two days per week might not lead to increased travelling to non-study activities. Overall, the participants think they will not travel more to certain activities but may plan them differently. Increased travelling by students seems to depend on the opportunities for activities and social contacts in their immediate residential area, and in addition, it may depend on car availability. However, this increased travelling will happen according to the concept of constant travel time budgets (TTB), which states: "that

over a large group of individuals, e.g. a country, people on average have quite stable travel time budgets of around 60–75 min per person per day" (Van Wee, 2015, p. 2). The existence of a constant TTB is disputed: it may be so that these travel time budgets are only constant at the most aggregate level (Mokhtarian & Chen, 2004). The requirement of surveying a huge group of students makes it challenging to prove whether the concept of constant TTP applies to student travel.

Study limitations and recommendations for future research

This small-scale qualitative research project, meant as a first exploration, reveals many of students' considerations. The (quantitative) extent to which these considerations affect a student's choice of travel mode or motivation to attend a course cannot be assessed with such a small group of participants associated with the same HEI. This exploration could be used to examine its findings on a larger scale. In future research, the high dependency on the context of the students' environment should be taken into account, especially infrastructural differences with the Dutch situation as explained in the introduction, implying the inclusion of multiple HEIs.

The participants had limited experience with online learning platforms for collaboration and practice purposes. Now that many students have experiences with online learning due to the COVID-19 pandemic, it would be interesting to compare our findings with the current perceptions, attitudes and preferences of students about online learning as a substitution for on-campus learning.

Analysis of the transcripts of the focus group meetings relied on the judgement of a single analyst. The analyses were conducted in four steps to lower the chances for subjectivity and potential bias, each from a different perspective (explained in section 3.3).

3.6 Conclusion

The influence that HEIs can have on a students' choice for low-carbon travel modes seems limited. Our findings show that their travel mode choices mainly depend on costs (having a free public transport permit) and an adequate infrastructure for bicycle and public transport (promoting reliability, convenience and safety), which are, in most cases, measures at a national level. HEIs can contribute to these measures by imposing parking restrictions for students. Although a HEI's influence on students' travel mode choice seems to be limited, there are opportunities to affect students' number of trips from residence to educational institution (and vice versa). Especially, schedule measures and creating online learning opportunities probably can make a difference. Therefore, we recommend that HEIs experiment with limiting on-campus learning to one or two days per week supplemented with online

learning. This has two major advantages: 1. a reduction of their carbon footprint by a decrease of education-related student travel and 2. a potential enhancement of the attendance rate of the courses. Furthermore, adding a virtual course environment to the physical learning space makes education much more flexible (time- and location-independent) (Vaughan, 2007). This is an important asset in light of the experience gained during the COVID-19 pandemic. A curriculum with such a course schedule should be designed as a responsible mix of face-to-face and online learning (so-called blended learning). Pedagogic principles, such as creating (digital) opportunities for sharing resources, discussion, getting feedback, reflecting on learning experiences and community-building, should be incorporated in this design. Such a hybrid or blended design may deliver a contribution to combatting climate change while at the same time ensuring educational quality. In either case, it sets an example to the students by practising what is advocated in the mission and vision of many higher education institutions.

Appendix

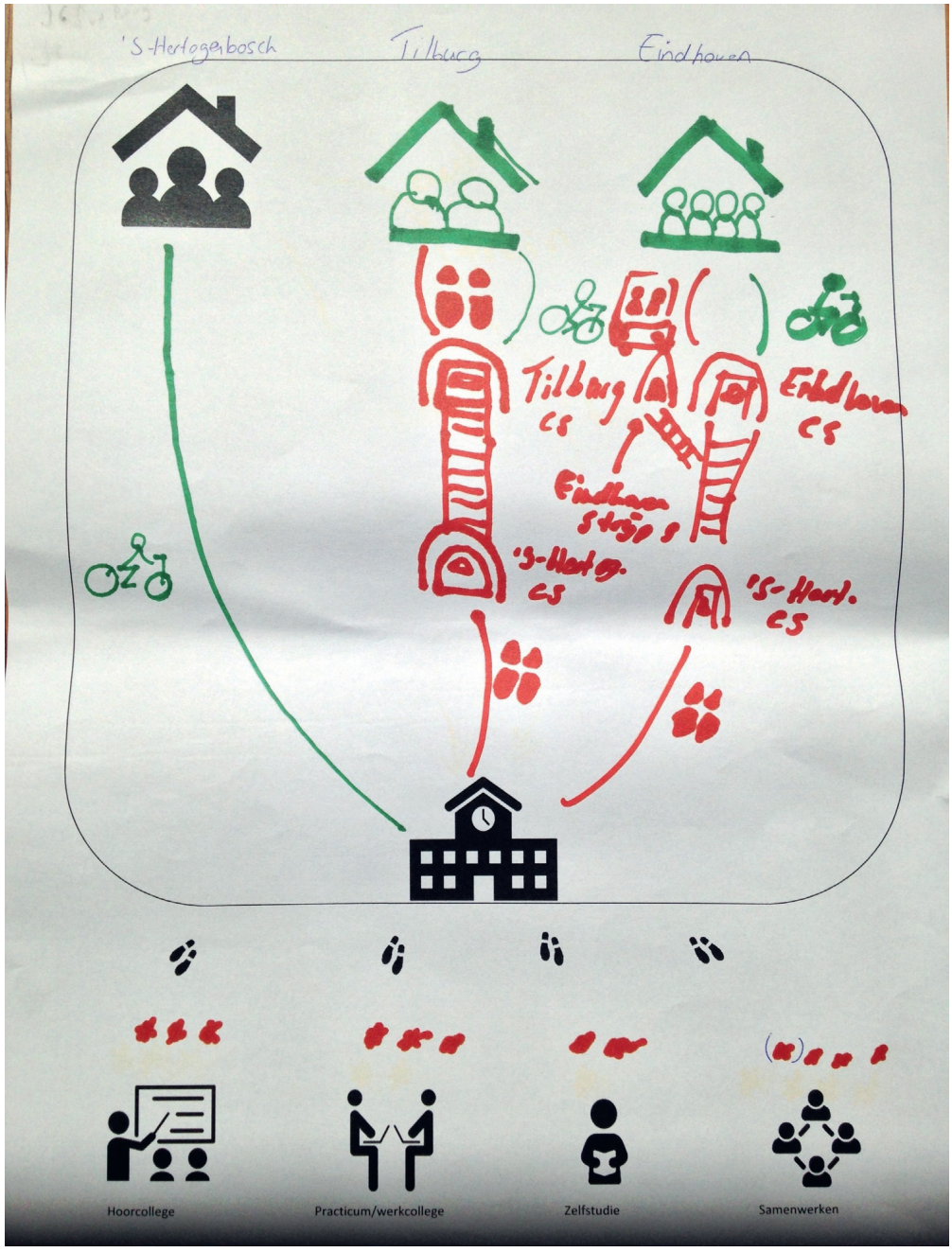


Fig. A1. Drawing of participant

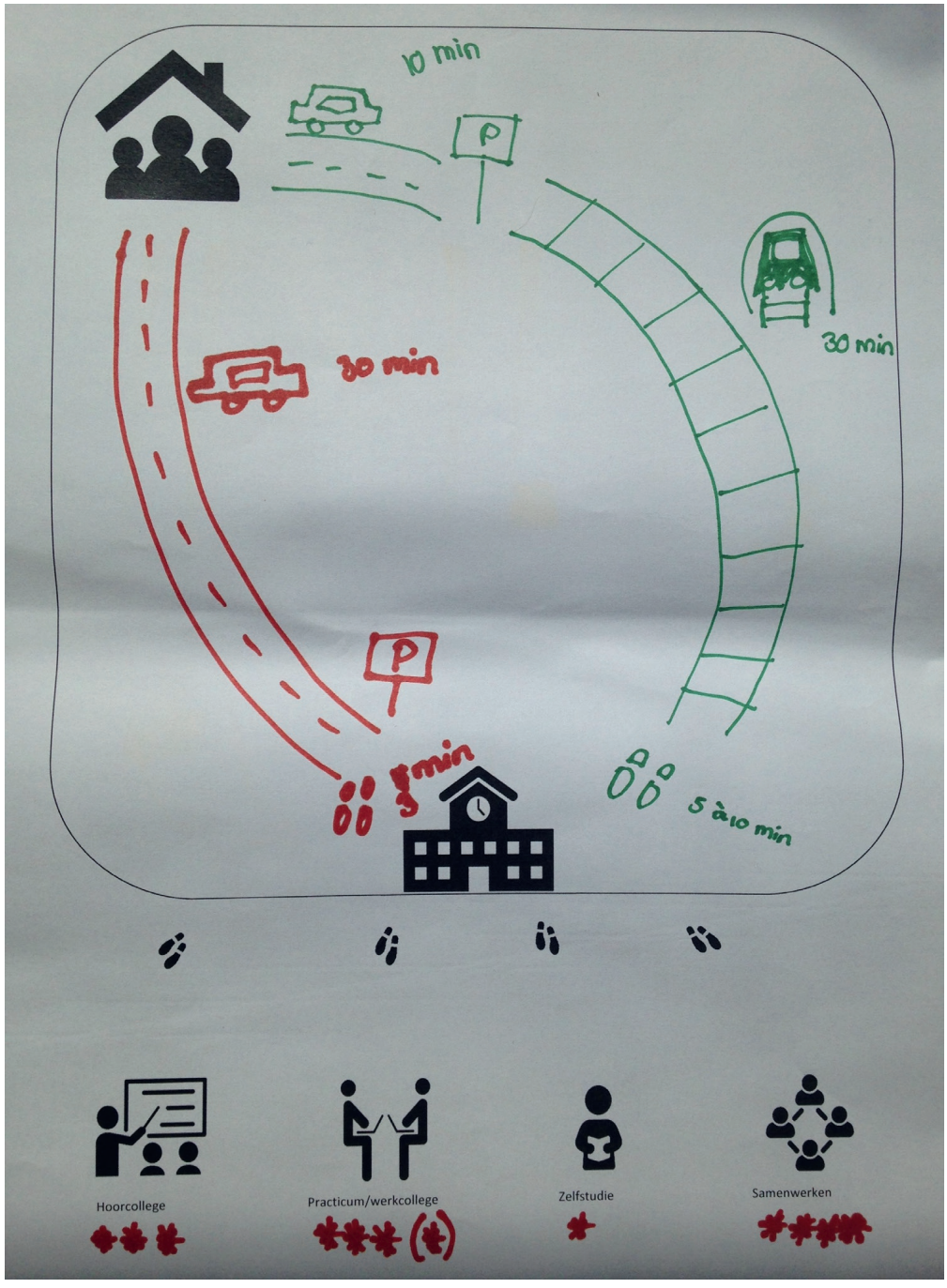


Fig. A2. Drawing of participant

Fig. A3. Icons for drawing

CHAPTER 4 Developing design principles for sustainability-oriented blended learning

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Abstract

Climate change forces higher educational institutions (HEI) to reconsider their traditional ways of teaching and organising education. This implies that they should reduce their impact on the environment and provide sustainability-oriented education. Blended learning (fusion of on-campus and online learning) may provide an appealing solution to achieve both objectives. It may reduce HEI's climate impact by reducing student travel to and from campus and also support the development of students' sustainability competencies. In this paper, pedagogical design principles and recommendations are developed to design such a sustainability-oriented blended learning configuration.

A realist review methodology is used to distil and develop pedagogical principles for blended learning. These principles were mirrored against pedagogical approaches that have been identified as suitable for developing sustainability competencies. This mirroring revealed some overlap but also some notable differences. Common principles include self-regulation, community building, discussion, knowledge management and collaboration but some principles identified in sustainability-oriented education are noticeably absent, including self-awareness, orientation towards sustainable change and interdisciplinary collaboration. The insights guide designing sustainability-oriented blended learning, and vice versa can also provide ideas for people working in off-line place-based contexts on sustainability-oriented education, to consider blended options.

Keywords: blended learning; sustainability competencies; design principles; travel behaviour; sustainability-oriented learning; pedagogical approach

4.1 Introduction

Seemingly unrelated developments in climate urgency and Information and Communication Technology (ICT) challenge higher education institutions (HEIs) to reconsider their traditional ways of teaching. To contribute to addressing climate change, HEIs should take measures to lower the climate impact of their organisation (Klein-Banai & Theis, 2013) as well as provide sustainability-oriented education (Wals, 2019), that can help develop and unfold the competencies students need in a climate-changed world (Brundiers et al., 2021; Wiek et al., 2011). Technical developments in ICT provide higher education (HE) with the possibility to create a virtual educational space adjacent to the physical space of the campus. This virtual space became the only space students could use for their learning during the COVID-19 pandemic when most HEIs made a rapid transition to, so-called, 'emergency remote teaching' (Marinoni et al., 2020).This forced response seems to have accelerated a development in HE to consider a mix of on-campus and online learning (so-called blended learning).

Blended learning (BL) can be deployed as a means to lower the climate impact of an HEI by reducing student commuting to and from campus (Versteijlen et al., 2017). Across the globe, students' travel to and from campus is a large contributor to carbon emissions. Visiting a virtual space is place-independent and can reduce travel movements and associated carbon footprints (Caird et al., 2015; Versteijlen et al., 2017). According to the study by Caird et al. (2015), distance-based HE teaching models (distance, online, ICT-enhanced) achieve carbon reductions of 83 per cent in comparison with on-campus models (in-class, ICT-enhanced). This is for the most part due to commute-related student travel, especially to universities and former polytechnics that provide no or very little on-campus housing. Indeed, the use of ICT also has a carbon footprint but one that is minor in comparison (Caird et al., 2015). Considering these findings, an educational design limiting on-campus learning to one or two days per week supplemented with online course delivery, thus reducing commute-related student travel, seems to be one obvious possibility for HE to meet its sustainability objectives. Combining on-campus learning, where student-student and lecturer-student interaction is crucial, with online learning might create an optimal learning environment both from an educational and a sustainability perspective. A focus on travel reduction can be seen as an institution´s effort to 'walk the talk' and can when combined with a broader vision of sustainability and an institution´s aspirations to help realise the Sustainable Development Goals (SDGs) (United Nations, 2020) also provide a way into strengthening students' sustainability competencies (Brundiers et al., 2021; Wiek et al., 2011).

In combining these two vantage points we come to the following overarching research question: how to design a blended learning configuration that can both reduce students' travel-related carbon emissions and enhance their competencies to meaningfully engage in sustainability challenges?

To be able to answer this question we first need to discuss what is meant by the educational

quality of BL. The sustainability competencies will be addressed in the next section. This study only considers the design quality of a blended course or curriculum, not the quality of management processes. It focuses on how a blended design can promote student learning. BL, like all education, has a normative aspect in that it willingly or unwillingly promotes certain values and behaviours. If reducing the environmental impact of HE on climate change by mitigating student commute is a normative aim then one of the indicators of a blended design should be the extent to which online learning is used to substitute on-campus learning to realise (and disseminate) this normative aim. In line with Allen and Seaman (Allen & Seaman, 2003), we call a course or curriculum blended when a large portion (typically anywhere between 30-80 per cent) is delivered online. However, to enhance educational quality, a blended educational design requires more than just adding ICT enhancements to on-campus courses as it constitutes a fundamental redesign of the educational approach (Bliuc et al., 2007; Vaughan, 2007). This is because BL changes or extends the mode of interaction with fellow students, lecturers, and content (Bliuc et al., 2007). BL can improve a student's engagement and learning outcomes (López-Pérez, Pérez-López, & Rodríguez-Ariza, 2011; Owston et al., 2013) but needs to consider factors such as, "educator presence in online settings, interactions between students, teachers and content, and deliberate connections between online and offline activities and between campus-related and practice-related activities" (Nortvig, Petersen, & Balle, 2018, p. 53) (p. 53). BL can be engaging for students and has the full attention of HE after COVID-19 (Ntim, Opoku-Manu, & Kwarteng, 2021), but it is unclear how it may support developing students' sustainability competencies. This study wants to make a contribution to fill that gap.

In summary, blended education comprises a responsible fusion of online and on-campus learning. The term 'responsible' is used because the fusion is characterised by using a pedagogical approach to integrate online and on-campus learning that is mindful of the normative aspect of education as well (Tassone, O'Mahony, McKenna, Eppink, & Wals, 2018). To gain insight into how to develop a responsible BL model we will answer the following (sub) research questions:

RQ1. What design principles characterise high-quality blended learning in higher education?

RQ2. To what extent does high-quality blended learning support students' development of sustainability competencies?

In the next section, some background is provided about education that aims to foster students ′ sustainability competencies in relation to BL. In the methodology section, the review approach will be introduced, followed by the results presented according to the research questions. In the last section, we end with a discussion of the results including suggestions for further research

4.2 Blended education for developing sustainability competencies

To determine educational strategies that can foster competencies which are essential for students to address the complex sustainability challenges in a climate-changed world, we first need to articulate what these competencies are. A competency is an in-situ combination of knowledge, skills and attitude, needed to accomplish the desired educational outcome (Brundiers et al., 2021; Lozano et al., 2019; Wiek et al., 2011). Brundiers et al. (2021) have collated and synthesised the sustainability competencies that have emerged in higher education contexts over the last decade or so. These competencies include systems thinking, strategic thinking, value thinking, futures thinking, interpersonal, intrapersonal and implementation competency. These competencies are interconnected, for instance, developing strategies for transformative change (i.e. strategic thinking) requires, analysing the underlying problem while considering the nested systems of which it is part (i.e. systems thinking), applying and assessing sustainability values while considering ethics (i.e.. value thinking), and considering future consequences (i.e. scenario thinking), using this knowledge and understanding to realise a solution to a sustainability problem or make an attempt to improve the situation (i.e. implementation) (Brundiers et al., 2021; Wiek et al., 2011). Every step of the process should be of an inter- or transdisciplinary and collaborative nature (Brundiers et al., 2021; Wiek et al., 2011). Next to these key competencies for sustainability, there are some general basic competencies which serve "as the foundation of academic sustainability education" (Wiek et al., 2011, p.211-212) such as critical thinking, research, data management and self-regulation skills. The educational challenge is to identify which pedagogical approaches are appropriate to develop these (key) competencies in students and, in our case, whether a BL design can be supportive or counterproductive. Two features emerge when considering a BL environment for developing students' sustainability competencies, namely, place-independency and just-in-time education. Place independency, as stated before, may affect the travel behaviour of students by decreasing their travel movements, but it can also widen the horizon for students. In BL, a student can use the virtual space to collaborate and interact with students from different disciplinary, national and cultural backgrounds together at a place and time of their choice without the environmental and financial costs of travel (De Kraker et al., 2014). This provides opportunities for developing interpersonal or transboundary competency, as De Kraker et al. (2014) calls it, by incorporating different perspectives while having group discussions and organised feedback (De Kraker et al., 2014). Moreover, this flexibility of time and place broadens access to learning opportunities (Caird & Roy, 2019).

Digital technology creates networks that connect not only people but also systems, establishing "a rapidly evolving information ecology" (Siemens, 2005, p.3). Today's certainties in the sciences technology, politics, economy, society and culture are constantly outdated by new insights (Pendleton-Jullian, 2019), making it vital to know how and where to find

reliable knowledge and, in addition, how this information can be interpreted in the context of social, economic and environmental issues. A complicating factor is also that the amount of knowledge, available through the World Wide Web and, more recently, AI-powered chatbots like ChatGPT (Farrokhnia, Banihashem, Noroozi, & Wals, 2023) has been increasing exponentially. For these reasons, learning cannot be a linear process of acquiring knowledge and skills anymore but should become a continuous process, lasting for a lifetime (Brundiers et al., 2021). Therefore, HE should prepare students for this just-in-time education (Gleason, 2018) and BL can probably provide an appropriate learning environment (Archambault & Warren, 2015)

4.3 Methods

What design principles characterise high-quality BL in higher education? (RQ1)
Introducing BL meets the key characteristics of a complex social intervention as formulated by Pawson et al. (Pawson et al., 2004). A BL intervention is embedded in the social system of the educational organisation, influenced by the motivations and intentions of the stakeholders (lecturers, management), and is susceptible to change due to different and changing circumstances. Subsequently, there is no prescription possible on how to design and implement BL and negotiation and feedback are necessary at each stage (Graham, Woodfield, & Harrison, 2013).
A realist review approach seems to recognise and address this complexity by considering the context of each experience. The aim of a realist review is explanatory: "what works for whom, in what circumstances, in what respect, and how?" (Pawson et al., 2004, p. 5). However, considering BL, the contextual factors influencing a blended design are never the same and possible design options are almost unlimited (Moskal, Dziuban, & Hartman, 2013), each of which constitutes an intervention to be studied in its own right. The ambition to meet the aim of a realist review while studying BL must be scaled back because such a complex system only allows "an understanding of partial and situated systems rather than whole and general ones" (Hinds & Dickson, 2021, p. 8). Therefore, a pragmatic approach was adopted to still make use of the explanatory strength of the realist review. This pragmatic approach is consistent with the iterative and flexible nature of realist review, rejecting standardization or prescription (Hunter, Gorely, Beattie, & Harris, 2022; Pawson et al., 2004). It entails:

- Empirical evidence is included in this study when it supports (or contradicts) at least one of the initial design principles extracted from theory.
- When considering how the context affects the intervention, the context is reduced to three typical blends between online and in-class education (Section Synthesise findings). Positive as well as negative effects are taken into account.

- Stakeholders are not consulted, although this is believed to be a key feature of a realist review (Hunter et al., 2022). Instead, the choice is made to discuss and refine the usability of the BL design principles for sustainability-oriented education through an additional literature review.

In this study, initial design principles are developed based on BL theories of authors leading in the field of BL science and the applicability of each of these principles is assessed in a variety of learning contexts by studying several empirical studies.

The systematic review approach consists of four stages (based on Pawson et al. (2004)) :

1. Develop initial theory. The initial design principles are extracted from theories about BL.
2. Search for literature. Evidence is gathered from empirical studies to test and refine these principles.
3. Extract and synthesise findings. By applying CIMO logic, that is, "in this class of problematic Contexts, use this Intervention type to invoke these generative Mechanism(s), to deliver these Outcome(s)" (Denyer, Tranfield, & Van Aken, 2008, p. 395), the findings are analysed and compared with the initial design principles.
4. Distil recommendations for practice. Recommendations are extracted from the findings

Although stages are defined, the process within each stage and between stages is iterative. New evidence may change the direction (Pawson et al., 2004).

Stage 1. Develop initial theory

The initial principles are extracted from three works of authors about blended/online learning, so-called programme theories. These works were chosen because they contain well-established theories and differ in perspective on how to design BL.

Laurillard (2013) specifies in the Conversational Framework the (iterative) interactions between students and lecturers and also fellow students linking both theory and practice. These interactions change while studying online or on campus (Laurillard, 2013). A strength of Laurillard's is that it captures the essence of teaching as an iterative dialogue between teachers and learners while functioning on the following levels: a discursive, theoretical, conceptual level; and an active, practical, experiential level, i.e., the levels bridged between teachers and pupils while engaging in the process of critical thinking and reflection.

Although the Conversational Framework includes interaction cycles during student collaboration, the social aspects of working together are not part of the framework. Garrison

and Vaughan (2008) fill this gap with their Community of Inquiry Framework, specifying the process of integrating social, cognitive, and teaching elements of a community of learners, collaborating in a blended setting.

Ellis and Goodyear (2013) developed a more, what we might call, Integrative Relational Framework by treating the learning environment as an ecology of learning (Jackson, 2019) in which online and on-campus learning is integrated and ecologically balanced, evaluating a student's approach to learning in this context (Ellis & Goodyear, 2013). This work aligns well with sustainability-oriented learning concepts (Wals, 2019).

Stage 2. Search for literature

A systematic, step-by-step approach was conducted to ensure transparency and rigour in searching the databases. We have chosen for two databases that allow for searching with logical operators and wildcards, that is, the ERIC library and Web of Science, both well-suited for education-related research.

Given that technological innovations are going fast and have a deep impact on the quality of online learning, the search was restricted to articles with a publication date after 2010. More pragmatically, this criterion also helped to keep the number of articles manageable. The search was conducted in May 2020. In all the searches the terms "blend* OR hybrid" (in title) and "higher education" were included. In the second iteration, we also added "OR flipped" in the in-title search term, as work on flipped classrooms also connects with this topic. Keywords were extracted from the initial design principles to be used as additional search terms and wildcards were added to capture similar (but not completely the same) terms used in the text (Table 4.1).

Table 4.1. Search expressions with keywords extracted from initial design principles (Table 4.5).

Design principle	**Search expression**
Learning process	"self-direct*" OR "self-regulat*" OR "self-navigat*"
Learning climate	affective OR "social presence" OR "personal relationship#"
Interaction and discussion	ritical discourse"
Acquisition and inquiry	acquisition OR "content knowledge" OR inquiry OR "cognitive presence
Practice	"practi*" OR "task#" OR "laborator*"
Collaboration	"collaborat*" OR "community of inquiry" OR "community of practice"

The database search started adding the search terms of all principles. As expected, this expression yielded no results in either of the databases. Every search expression was added separately and in combination with others, which eventually resulted in 22 searches. After deleting duplicates, the result list contained 230 articles. These 230 articles went through a

Table 4.2. Summary of selection criteria. Based on (Ellwood, Grimshaw, & Pandza,2017)

Filter	Method	Reasons for exclusion	Papers remaining
0	Bibliographic searches		230
1	Reading of abstract	Studies not situated in higher education Studies not about didactical issues Studies about specific tools, devices, or learning activity Not regular higher education, i.e. adult education Studies not reviewed About mobile technology BL in a special context (minority groups, virtual world) Solely a comparison of online and BL Study of adoption of BL in the institution	85
2	Reading of full paper	Same as filter 1 Not substantially substituting face-to-face with online learning Research situation mainly online, not blended Described intervention not relevant to the design principles Review Only describing the didactical model, no mechanisms are mentioned BL intervention is not clearly described Validity of the results Research is focussed on teacher experiences Only outcomes are specified, not the mechanisms leading to these outcomes Intervention is a technology decreasing in popularity among students (Twitter) The blend is specific for a special profession	27
3	Backward snowballing	Extracting empirical studies from the references list of a (recent) review (Nortvig et al., 2018) about BL and repeating filters 2 and 3.	38

filtering process (Table 4.2). During the filtering process 'Reading the full paper', the paper was also assessed by using guiding questions based on CIMO logic (Table 4.3). In the end, 38 studies remained for analysis.

Table 4.3. Research questions based on CIMO logic. Based on: (Holmström, Tuunanen, & Kauremaa,2014)

Component	Research questions
C - Context	What is the learning context (Institution, nr of students, study phase, subject)?
	What research method is applied?
I - Interventions	What actions, executed online or face-to-face, are formulated by the designer(s) for implementing a BL intervention that applies to one or more of the initial design principles?
M - Mechanisms	What are the underlying generative mechanisms triggered by the intervention in a certain context, indicating why the intervention produces a certain outcome?
O - Outcome	What are the results of the interventions in their various aspects?

Stage 3. Extract and synthesise findings

Data extraction forms based on CIMO logic were developed and populated with the extracted data of each paper. The next step in this stage was comparing and contrasting the findings from the different studies and finally, the results were compared with the initial design principles of stage 1.

Extracting data

The theoretical knowledge base about experiences with BL is structured by using CIMO logic (Denyer et al., 2008) (Table 4.3). A step-by-step approach to extracting the empirical findings about the initial design principles is applied:

1. The 38 articles were uploaded in ATLAS.ti (version 8) and coded according to CIMO logic. Every article received codes like ['C','I','M','O']_[nr of article]_[acronym of design principle], for instance, "C_2_SLE". The acronym of the design principle can be retrieved from Table 4.5.
2. Appropriate data were extracted from each article and ordered according to CIMO logic.

Synthesise findings

In the next step, the findings from the 38 papers were analysed and synthesised with the programme theories. To include contextual data, a context table (Appendix A) was created in which data has been gathered about some characteristics of the students involved in the study (age and study phase), the course subject, and the didactic method applied. Through the reference, all mechanisms and recommendations can be traced back to their context. The design of the BL configuration was generalised according to three typical blends between online and in-class education, namely; 1. online: knowledge acquisition and in-class: practice

(so-called flipped learning), 2. practice and knowledge acquisition more or less equally divided between online and in-class learning and 3. practice and knowledge acquisition more or less equally divided between online and in-class learning supplemented with collaborative learning. For each of these learning configurations, the associated mechanism (positive change and areas of concern) were gathered per design principle. Finally, these findings were compared with the programme theories and the initial design principles were, if required, adapted to evolving insights.

Stage 4. Distil recommendations for practice

Recommendations to optimise a BL configuration are extracted from the synthesised findings (generative mechanisms (positive change and areas of concern) in the different contexts).

To what extent does high-quality blended learning support students' development of sustainability competencies? (RQ2)

The general BL design principles are mirrored against what is needed to develop sustainability competencies and the corresponding pedagogical approaches. We based our analysis on well-cited references in literature about sustainability-oriented education or making the connection of sustainability with online learning in higher education (Table 4.4).

Table 4.4. Consulted scientific studies about sustainability oriented learning.

Subject	Scientific literature	
Sustainability competencies	(Wiek et al., 2011)	A highly-cited review article providing a framework of key sustainability competencies to be used in HE
	(Brundiers et al., 2021)	A further elaboration on the key competencies of Wiek et al. (Wiek et al., 2011)
	(Lozano et al., 2019)	A framework of 12 sustainability competencies, to be used in HE, is connected to pedagogical approaches to develop these competencies
Pedagogical approach for sustainability	(Lozano et al., 2017; Lozano et al., 2019)	A framework of 12 sustainability competencies connected to 12 pedagogical approaches, classified into three categories.
	(Tejedor et al., 2019)	Focus on didactic strategies relevant to the development of sustainability competencies.
	(Wals, 2019)	Key characteristics of a sustainability-oriented ecology of learning supplemented with an underlying emancipatory pedagogy.
Empirical studies: online	(Sibbel, 2014)	Exploration of the potential of a BL course conducted with a constructivist approach and principles of knowledge management, to promote education for sustainability
Learning and sustainability	(Archambault & Warren, 2015)	Study of a blended course, Sustainability Science for Teachers, integrating the use of technology and digital storytelling to engage students in sustainability topics.
	(Hesen, Wals, & Tauritz, 2022)	Fostering subjectivation and creating a sense of community in an online course on Environmental Education for Sustainable Living
	(De Kraker et al., 2014)	Application of an effective learning environment to foster transboundary competency through virtual mobility

4.4 Results

Design principles of BL (RQ1)

The findings are presented according to stages 1 and 3 of the realist review approach. Stage 2, the literature search, resulted in 38 studies (Appendix A). These studies are analysed and interpreted in stage 3 using the initial design principles. The resulting recommendations are derived from stage 3.

Stage 1. Developing initial design principles

The selected authors developed well-established theories that give direction to the design of a BL configuration. The initial design principles are extracted from these programme theories which will be discussed first.

Programme theories

Diana Laurillard, Teaching as a design science

Laurillard (2009) developed the Conversational Framework based on a synthesis of former pedagogical research about what it takes to learn. This general framework represents learning and teaching in any form, conventional or technology-enhanced. It specifies the iterative transactions between student–teacher and student–fellow students on two contrasting levels: 1. articulating and discussing theory and 2. experimenting and practising on goal-oriented tasks. In Teaching as a Design Science, Laurillard (2013) builds upon the Conversational Framework to design education with digital technology and in particular discusses the design of learning activities for this pedagogical technologically-enhanced approach. These activities are learning through acquisition of knowledge, applying theoretical concepts into practice, inquiry making use of resources, peer discussion, and collaboration to construct a shared outcome (Laurillard, 2013).

Randy Garrison and Norman D. Vaughan, Blended Learning in Higher Education, Framework, Principles and Guidelines

Garrison and Vaughan (2008) describe the educational processes of a community of students in the Community of Inquiry Framework. The core elements of this framework are social presence, teaching presence and cognitive presence. Social presence is about cultivating a community where students can develop personal relationships. Teaching presence "provides the design, facilitation, and direction for a worthwhile educational experience" (p.31) and cognitive presence "maps the cyclical inquiry pattern of learning from experience through reflection and conceptualization to action and on to further experience" (p.29). This framework is used to introduce seven design principles for BL (Garrison & Vaughan, 2008). These principles provide direction as to how the teaching presence of a lecturer can create and sustain a social and cognitive presence.

Robert Ellis and Peter Goodyear, Experiences of e-learning in Higher Education: the ecology of sustainable innovation

Ellis and Goodyear (2013) consider how students learn within the larger environment in which they study. They address this learning environment as an "ecology of learning" with 'good learning' as a common goal for students, teachers, service providers, leaders and society. An ecological balance should be maintained in a rapidly changing world, for example, consider technological innovations. According to Ellis and Goodyear (2013) , students are looking for a balanced use of technology, not reducing access to their teachers. In their Integrative Relational Framework, Ellis and Goodyear (2013) argue that an effective replacement of a portion of face-to-face experience by e-learning is "one that seeks harmony of the parts, is integrated and ecologically balanced to focus students on learning outcomes and the development of understanding" (p.75). They think that two learning activities are particularly suitable for e-learning, namely learning through discussion and learning through inquiry (Ellis & Goodyear, 2013).

Initial design principles

Following Laurillard (2013), the first design principles developed (Table 4.5: ID, AI, PR, CO) are based on the learning activities in which the students participate, that is, learning through discussion, acquisition, practice, and collaboration. Next, a design principle about creating a safe and social learning environment (Table 4.5: SLE) was added to the principles based on the element "social presence" in the Community of Inquiry framework of Garrison and Vaughan (2008). In addition, learning by discussion (Table 4.5: ID) is supplemented with the term 'interaction', indicating an unstructured form of a student's interactions with the lecturer and fellow students. All three authors emphasise the importance of the learning process principle (Table 4.5: LP). The programme theories provided design principles and the effect they may have when applied adequately in BL (Table 4.5).

Table 4.5. Initial design principles for a BL configuration

Design principle	**(Laurillard, 2013)**	**(Garrison & Vaughan, 2008)**	**(Ellis & Goodyear, 2013)**
Aiming at self-regulation of learning and practice in a student's learning process (LP)	Coached by the lecturer but learning independently (using the internet), fosters a context in which a student can develop self- efficacy beliefs, important for academic experiences	To shape cognitive and metacognitive processes and learning, students should aim at becoming self-directed, best explored in a face-to- face context and reflected upon in an online context.	Learning is self-regulated and goal-oriented. Opportunities should be created to make personal choices concerning goals, study and assessment methods, place and time.
Fostering a safe and social learning environment (SLE)	A lecturer should try to create for the student a sense of belonging to a group. It can change a student's attitude towards academic work.	The term 'social presence' indicates that students in a community of inquiry should develop an environment in which they feel safe to express themselves and challenge ideas. In-class learning establishes this environment.	Learning activity is socially situated, that is, being a part of a learning community affects students' approach to learning through relationships with other people.

Design principle	(Laurillard, 2013)	(Garrison & Vaughan, 2008)	(Ellis & Goodyear, 2013)
Facilitating interaction and discussion among fellow students and with the lecturer to stimulate reflection and critical thinking (ID)	During the interaction cycles of the student with a lecturer and fellow students' concepts, goals, or practice capabilities are modulated and will generate in this way new actions in a continuous iterative process of development and learning. In an asynchronous online discussion, a student has time to reflect, modify and articulate their contribution.	A strong 'teaching presence' is necessary to shape the interaction between students into a reflective and critical discourse. Online learning supports reflection and in-class learning, verbal agility and spontaneity.	Online learning should use the opportunities of interactivity, adaptivity and 'intelligence' in the online resources, and rich human-human communication. Discussing and understanding each other's positions on significant (real-world) issues is an important aspect of academic learning.
Transforming learning through acquisition and inquiry into an active process based on existing knowledge (AI)	To activate learning through acquisition (teacher communication cycle) the lecturer must 1. create a sense of need to know, 2. use familiar concepts, 3. use multiple representations of a concept and 4. use the principles of the cognitive load theory.	The term 'Cognitive presence' indicates learning through inquiry. Online discussions encourage a more integrated and deeper level of thinking. Face to face discussions are conducive to creating new ideas and task management.	Every student has their unique approach to constructing knowledge by using 1. past experience and existing knowledge and 2. a surface or deep approach to learning. Learning through inquiry: an active, authentic and student centred form of learning
Working on authentic tasks with scaff olded and theory based practice (PR)	The lecturer provides exercises that are in a student's zone of proximal development and contain formative intrinsic feedback. Students may use these exercises to reflect upon and adapt their conceptual understanding, studying online.		Online learning methods and tools can create opportunities to support the transfer of learning from the classroom to the professional setting by designing online learning tasks and tools which align with the workplace setting.
Collaboration for constructing a shared outcome through participation and negotiation with fellow students (CO)	Students can learn from each other and get motivated by practising with one another. A Computer Supported Collaborative Learning Environment can promote this process of articulating and critiquing points of view.	The learning environment of a community of inquiry integrates social, cognitive, and teaching elements and stimulates critical reflection and discourse.	The participation of students in a community of practice is inseparable from learning.

Stage 3. Extract and synthesise findings

In the following sections, the identified mechanisms (positive change and areas of concern) will be discussed and compared with the initial design principles (stage 1) for each principle. The initial design principles will be adapted if there is a reason to do so. The reference can be used to trace back the context of the BL intervention in the context table (Appendix A).

Aiming at self-regulation of learning and practice in a student's learning process

In BL, a student needs to have or develop the ability to structure and plan the learning part outside the classroom (Brewer & Movahedazarhouligh, 2019; Sivapalan, 2017; Tsai, 2014; Xiu, Moore, Thompson, & French, 2019; Xiu & Thompson, 2020; Zhu, Au, & Yates, 2016). The student's learning outcome is affected by their level of self-control (dispositional personality characteristic) and self-regulation at the beginning of the blended course (Traver, Volchok, Bidjerano, & Shea, 2014; Zhu et al., 2016), although self-directedness (metacognition and motivation) has been found as a more significant influencing factor for performance in flipped learning (Lee, Jihyun & Choi, 2019; Sivapalan, 2017). In addition, the self-efficacy beliefs of students are found as a significant predictor of their learning performance (Xiu & Thompson, 2020). Coaching and motivating students to study regularly seems to be necessary, illustrated by the observations of students, following a flipped learning course, who experience the online learning part as time-demanding and feel pressure to go to class prepared (Brewer & Movahedazarhouligh, 2019; Xiu et al., 2019).

Therefore, several approaches are mentioned in the reviewed studies to coach and motivate students. At the beginning of the course, or even before, it is recommended to offer pre-course orientations and in-course intervention for students new to the online learning environment (Traver et al., 2014). During the course, to encourage students to study regularly, direct feedback on their performance is stimulating (Tsai, 2014). This feedback can be provided by online tests and quizzes (Cabrera, Villalon, & Chavez, 2017), but also by the lecturer, whose presence should be apparent throughout the course in supporting the students (Sidebotham, Jomeen, & Gamble, 2014; Xiu et al., 2019). Additionally, online feedback from fellow students can be helpful, but this needs scaffolding because students are reluctant to record criticism online of their peers' work (Sivapalan, 2017; Tambouris, Zotou, & Tarabanis, 2014). And lastly, a digital learning environment can have learning analytics functionality that automatically generates warnings to students if they spend insufficient time on their tasks (Lee, Jihyun & Choi, 2019). Fellow students can also play a stimulating role when students get the opportunity to implement their tasks in a team project (Baranova, Khalyapina, Kobicheva, & Tokareva, 2019; Tsai, 2014). In this way, they can experience other students' processes and work. This increases motivation and positive competition (Saghafi, Franz, & Crowther, 2014). Considering the participation of an individual student, this is positively affected when there is a choice between online assignments meeting his/her learning style (Cheng & Chau, 2016). Additionally, gamification elements can be added to the blended design, although these

elements were not in all cases effective (Mese & Dursun, 2019).
Although self-regulation seems to be difficult for some students (Spadafora & Marini, 2018), they appreciate the opportunity to study anytime and anywhere (Hall & Villareal, 2015; Powers, K. L., Brooks, Galazyn, & Donnelly, 2016).
Adapting learning materials to the different learning styles of students to enhance motivation is hardly mentioned in the programme theories. Ellis and Goodyear (Ellis & Goodyear, 2013) state that lecturers should stimulate students to take control of their learning process by helping them to make their own choices. They mention 'empowering learners' through loosening administrative (place, time and study costs) and educational (goal, study and assessment methods) constraints as an opportunity for online learning (Ellis & Goodyear, 2013).

Fostering a safe and social learning environment
The programme theories emphasise the importance of an environment in which students can develop relationships with other people and feel safe to express themselves. This is confirmed by several reviewed studies (Lee, Jieun & Bonk, 2016; Sidebotham et al., 2014; Spadafora & Marini, 2018; Turula, 2018). These studies add some best practices and propose strategies how to foster emotional closeness online as well as in class.
In-class activities can foster emotional closeness. If a lecturer provides opportunities for interaction and thus creates a friendly atmosphere, social connections can be made (Sidebotham et al., 2014; Spadafora & Marini, 2018). This is especially important at the beginning of the blended course (Hall & Villareal, 2015). If there is limited time for interaction during in-class sessions, online blogging activities for students may be the solution to improve emotional closeness (Lee, Jieun & Bonk, 2016; Wang, M., 2010). An example is an assignment in which students wrote weekly reflective journals about their learning and personal experiences and commented on the journals of fellow students (Lee, Jieun & Bonk, 2016). However, it is important to note that not receiving comments or replies from fellow students on your journal or posts on the discussion board can be experienced as unfinished (Hall & Villareal, 2015). As for the discussion board, experience showed that students did not feel comfortable writing online about certain topics but could discuss them in class (Hall & Villareal, 2015). Regarding the lecturer's social presence, online asynchronous video feedback can be helpful. One of the reviewed studies showed that hearing and seeing a lecturer during video feedback created "a sense of closeness" with the lecturer (Borup, West, Thomas, & Graham, 2014).
Finally, the collaborative construction of knowledge in an online learning environment while working on an assignment or assessment creates a sense of community (Vaughan, 2010). Still, online collaboration can isolate some students, negatively affecting their motivation and enjoyment (Saghafi et al., 2014).

Facilitating interaction and discussion among fellow students and with the lecturer to stimulate reflection and critical thinking

Interacting for learning can be considered as an iterative cycle of a student with a lecturer or fellow students (Laurillard, 2013) and can have varying purposes, for instance, having a social conversation, delivering feedback or clarifying the content. In addition, in a more structured form, it can be used to discuss certain topics, encouraging the student to reflect, think critically, and understand the positions of others (Ellis & Goodyear, 2013; Garrison & Vaughan, 2008). Interaction can take place face-to-face or, location-independently, online. When interacting online, there is a choice between interacting synchronously or asynchronously in time. According to several reviewed studies (Cheng & Chau, 2016; Hall & Villareal, 2015; Lee, Jieun & Bonk, 2016; Northey, Bucic, Chylinski, & Govind, 2015; Sivapalan, 2017; Turula, 2018), these elements, that is, purpose, place and time synchronicity, should be considered in the design of BL. For instance, if the purpose is 'meeting new classmates', a better choice probably is meeting face-to-face because meeting online with new classmates was described by students as more difficult (Hall & Villareal, 2015). In a study about blended tutoring, the face-to-face encounters (one-to-one basis) as well as the asynchronous online exchanges with the tutor, were valued by the students. Face-to-face tutoring had the advantage of direct contact with the tutor, while asynchronous online tutoring provided the students with time to think before answering the tutor's questions. The latter resulted in a deeper level of processing of the exchange and higher levels of critical thinking (Turula, 2018). A comparable mechanism has been observed during in-class discussions and asynchronous online discussions. Mainly students with a deep approach to learning value asynchronous discussions for the opportunity to reflect on the topics discussed, allowing for an in-depth exploration (Bliuc, Ellis, Goodyear, & Piggott, 2011; Sivapalan, 2017). Direct contact during in-class discussions allows for elaborations and spontaneous questions, ensuring a better understanding of the content (Hall & Villareal, 2015). Regarding online discussions, a discussion board should contain clear instructions that motivate students to explain, clarify and support a topic (Hall & Villareal, 2015), because superficial responses in the discussion board lead to disengaged students (Hall & Villareal, 2015). A student's engagement is essential because they seem reluctant to use a discussion board, probably because challenging opinions (recorded) may cause a conflict between classmates (Tambouris et al., 2014). In collaborative BL, a discussion board can be part of an online collaboration environment. Besides discussion, this environment can be used for social and task-oriented interaction, thus documenting the process (Tambouris et al., 2014; Wang, M., 2010). Successful experiences are using an accessible medium like Facebook for asynchronous learning (Lee, Jieun & Bonk, 2016; Sivapalan, 2017). Incorporating asynchronous components, such as social networking and blogs, extend the learning environment and probably increases engagement (Lee, Jieun & Bonk, 2016; Northey et al., 2015).

Synchronicity in time seems to make an essential difference if it comes to learning by discussion. An asynchronous discussion provides the student with time to think and explore

before formulating a reasoned reply on a discussion topic. Therefore, the term '(a}synchronous' is added to the design principle. This becomes Facilitating (a)synchronous interaction and discussion among fellow students, and with the lecturer (...).

Transforming learning through acquisition and inquiry into an active process based on existing knowledge

For learning, students use strategies compliant with their learning style (Picciano, 2009). Some prefer visuals, others audio or text. Different representations of content meet this diversity and help students to learn (le Roux & Nagel, 2018). In BL, in most cases, a Learning Management System (e.g. Blackboard) handles the delivery of a variety of multimedia content, that is video lectures (Hall & Villareal, 2015; le Roux & Nagel, 2018; Lee, Jihyun & Choi, 2019; McLean, Attardi, Faden, & Goldszmidt, 2016; Sivapalan, 2017; Xiu et al., 2019), videos (Brewer & Movahedazarhouligh, 2019), interactive voice-over slides (McLean et al., 2016), instructional videos (Deegan, Wims, & Pettit, 2016), an interactive online textbook (Bolsen, Evans, & Fleming, 2016; Powers, K. L. et al., 2016), computer-mediated tutorials (Turula, 2018), podcasts (Sidebotham et al., 2014), supplemented with synchronous in-class (Akkaraju, 2016; Han & Ellis, 2020; Lee, Jihyun & Choi, 2019; Saghafi et al., 2014; Spadafora & Marini, 2018; Zhu et al., 2016) and online lectures (Saghafi et al., 2014; Spadafora & Marini, 2018). In addition, content can be prepared and delivered by students in face-to-face and online tutorials (Bliuc et al., 2011). Asynchronous online content delivery has a great advantage that it can be viewed, read and listened to multiple times, which helps students better understand the theory (le Roux & Nagel, 2018; McLean et al., 2016; Xiu et al., 2019). Still, there is a risk that students will not immerse themselves in the material. A non-interesting video can be turned off (Hall & Villareal, 2015). One way to avoid such behaviour is by delivering short online presentations with attention-grabbing audio and visual components (Hall & Villareal, 2015). Another risk is that students do not understand or misunderstand the content delivered (le Roux & Nagel, 2018; McLean et al., 2016; Xiu et al., 2019). To verify students' understanding of the concepts, online quizzes, formative tests or Q&A could be used (Brewer & Movahedazarhouligh, 2019; le Roux & Nagel, 2018; McLean et al., 2016; Xiu et al., 2019). These instruments are also useful for students with a knowledge gap (Akkaraju, 2016; Quinn & Aarao, 2020). In addition, especially used in flipped learning, the in-class meeting could be started with a quiz and review of the topics covered, resulting in a deeper conceptual understanding (Akkaraju, 2016). Although online delivery provides for much more opportunities to meet the different learning styles of students, their approach to learning does not seem to change. Students with a deep or surface approach to learning in a face-to-face context show the same approach in an online context (Bliuc et al., 2011). To motivate their students, a blended course about evidence-based practice and research situated learning in the professional practice environment and also provided access to learning materials at a convenient time (Sidebotham et al., 2014). Another strategy to stimulate the participation of students is to relate the students' own experiences with the topic/theoretical concepts of the course (Cardak & Selvi, 2016; le Roux & Nagel, 2018).

This corresponds with the programme theories about knowledge acquisition, in which the focus lies on arousing an intrinsic curiosity in the student or, as Laurillard (2013) puts it, "a sense of need to know" (p.113). This beholds that the content delivered should be relevant to the student. Relevancy of content can be achieved by aligning this content to the student's own experiences (Ellis & Goodyear, 2013; Laurillard, 2013). A learning activity suitable for activating students for knowledge acquisition is inquiry-based learning, as they have to take responsibility for their learning (Ellis & Goodyear, 2013; Garrison & Vaughan, 2008; Laurillard, 2013).

Working on authentic tasks with scaffolded and theory-based practice

Strategies mentioned to encourage students to work on their tasks include 1. providing a choice of assignments that match students' learning preferences (Cardak & Selvi, 2016; Cheng & Chau, 2016), 2. supplying assignments with intrinsic feedback (Hall & Villareal, 2015) and 3. embedding the assignments in a real-world context (Tambouris et al., 2014). An example of the first strategy is an assignment that can be carried out by applying information access, interactive learning, networking, and materials development (Cheng & Chau, 2016). Although most students opted for information access, the students choosing networking and materials development showed more satisfaction with their work (Cheng & Chau, 2016). An example of the second strategy is allowing several attempts while making online assessments (Hall & Villareal, 2015). This reduced anxiety provided extra practice and encouraged students to explore concepts (Hall & Villareal, 2015). Additionally, an experiment with a dedicated interactive learning environment, involving first-year students, showed the value of instantly receiving feedback. It made independent learning possible, thus activating critical thinking skills (Powers, K. L. et al., 2016). It also exposed time management and technical problems of students, resulting in a decrease in exam grades, probably because the students in the blended section spent less time on the course materials than their fellow students in the traditional sections (Powers, K. L. et al., 2016). An example of the third strategy is a project-based course using a blended Problem-Based Learning (PBL) design. In PBL, students build and apply new knowledge in a real-world context (Tambouris et al., 2014). In this course, digital cognitive tools for documentation, argumentation and organisation were used to scaffold the PBL process (Tambouris et al., 2014). It revealed that scaffolding is essential in self-directed learning strategies such as PBL (Tambouris et al., 2014).

Laboratory classes need their physical surroundings. Still, there are possibilities to exercise these skills in a virtual environment. The experiences with a blended arrangement, that is, alternating virtual lab exercises with experiments performed in a physical lab are mainly positive (Deegan et al., 2016; Enneking et al., 2019; Son, 2016). A virtual lab has the advantage of the possibility to repeat the exercise as much as needed. This resulted in building self-confidence among students in their knowledge and abilities (Deegan et al., 2016). Still, another experience, a chemical lab, mentions that blended laboratory students felt less comfortable handling chemicals than traditional laboratory students and also, were less convinced of the

value of their learning for their professional careers (Enneking et al., 2019).
A study about design studio education, supported by a real-time web-conferencing tool (synchronous mode), and Blackboard and Facebook (asynchronous mode), revealed that a physical classroom facilitates the exchange of ideas, practice and learning from fellow students and a virtual classroom, reflection on their process and, asynchronously, researching new concepts (Saghafi et al., 2014).
The programme theories confirm some strategies to encourage students to work on their tasks. Ellis & Goodyear (2013) advocate the design of authentic online learning tasks and tools to stimulate the transfer of learning to professional conduct. The programme theories make no mention of adapting assignments to students' learning preferences. It is added to the design principle. Especially Laurillard (2013) emphasises the importance of formative intrinsic feedback.

Collaboration for constructing a shared outcome through participation and negotiation with fellow students
In a flipped as well as in a blended model collaborative working on tasks or a project motivates students to spend a great deal of time on their studies (Baranova et al., 2019; Cabrera et al., 2017; le Roux & Nagel, 2018; Vaughan, 2010). Collaborative learning is of particular importance if contact time is limited or in the case of a large class (le Roux & Nagel, 2018). To improve active and collaborative learning in a digital learning environment, facilitating online interaction, project organisation and documentation is essential (Han & Ellis, 2020; Vaughan, 2010). Therefore "in a technologically-enhanced learning environment" is added to the design principle.
In BL, students with a deep learning approach, collaborating with students with a similar approach, have the most successful learning experience, in academic performance as well as in using effective strategies for collaboration (Han & Ellis, 2020)
The programme theories emphasise the importance of learning through collaboration. The participation of students in a learning community stimulates critical reflection and discourse (Garrison & Vaughan, 2008; Laurillard, 2013) and learning from each other (Laurillard, 2013). In addition, it influences students in how they approach their work (Ellis & Goodyear, 2013).

Blended learning for developing students' sustainability competencies? (RQ2)
The realist review yielded six design principles and corresponding recommendations (Table 4.6) on how to design blended education. The remaining question is whether and how this BL design may support the development of sustainability competencies.

General design principles
The first design principle is about a pedagogical approach that stimulates self-regulation in a student's learning process. In a BL environment, students get more control over when, where, what and how to learn. A virtual space adjacent to the physical space adds more spaces

for discussion, conversation, exploration, acquisition, practice, reflection and so on. In a well-designed BL configuration, balancing online and in-class activities, a student can, to a certain extent, integrate spaces, places, activities and resources to fit his or her own needs and learns how to create and implement their learning ecology (Jackson, 2019). So, having more control and autonomy as well as more possibilities in time and place helps a student to develop the self-regulation skills that are essential in BL. In addition, BL utilises technological tools that can support students, for instance, by providing relevant and personalised content and assessment and tracking their learning performance (Alamri, Watson, & Watson, 2021; Boelens et al., 2018; Caird & Roy, 2019). Self-regulation skills are also needed in a dynamic professional environment where technological innovations, globalised competition and environmental demands ask for flexibility, responsiveness to change (Bohle Carbonell & Dailey-Hebert, 2021) and a responsible attitude. To prepare a student for taking a role in such an environment not only self-regulation is important but also self-awareness of one's own values regarding sustainability issues (Brundiers et al., 2021). Brundiers et al. (2021) call this the intrapersonal competency and add it to the key sustainability competencies of Wiek et al. (2011) . Developing an intrapersonal competency corresponds with what Biesta (Biesta, 2020) calls 'subjectivation', meaning, awareness as an individual of "our freedom to act or to refrain from action" (p. 93). Hesen et al. (2022) add, in the context of sustainability, "bound by the ecological boundaries in which this becoming occurs" (p. 86). To conclude, to be suitable for developing students' sustainability competencies, not only self-regulation should be the objective in the student's learning process but also self-awareness. The second design principle is about fostering a safe and social learning climate. A safe learning climate can lead to students feeling free to be creative and critical and take on new challenges, unafraid of the risk of failure (Barab, Arici, Aguilera, & Dutchin, 2019; Hesen et al., 2022; O'Toole, Hayes, & Halpenny, 2019). This feeling of freedom to express oneself is, according to Hesen et al. (2022), a prerequisite in search of the self (subjectivation or intrapersonal competency) and also, in collaborating while taking different perspectives into account (transboundary (De Kraker et al., 2014) or interpersonal competency (Wiek et al., 2011). In BL, creating a safe and social learning climate is perceived as a challenge (Boelens et al., 2017). Having to communicate in a digital learning environment, "can isolate some students detrimentally affecting their motivation and enjoyment" (Saghafi et al., 2014, p. 537). Boelens et al. (2017) mention several ways for lecturers to contribute to a safe and social learning climate: "showing empathy, having a sense of humour, providing encouragements, directing attention to task-relevant aspects, and attending to students' individual differences" (p. 4). In addition, several recommendations (RC6-RC11) for fostering a safe and social learning climate are extracted from the BL studies. This design principle seems equally important for BL as sustainability-oriented learning.

Design principles for applying didactic methods

The last four design principles are about learning methods in which students interact and discuss, acquire knowledge, bring theoretical knowledge into practice and collaborate for constructing a shared outcome (Table 4.6). As presented in section 4.2, living in a rapidly evolving information ecology, students need to learn how to learn. Passive knowledge acquisition during a lecture is no longer adequate and should be transformed into a more active process in which discussion, acquisition, practice and collaboration are interwoven, according to the Conversational Framework (Laurillard, 2013). Lecturing has a low likelihood of addressing any of the sustainability competencies (Lozano et al., 2019) in contrast with a participative and research method such as project and/or problem-based learning which can address all sustainability competencies, as defined by Lozano et al. (2019), especially, inter-disciplinary work, anticipatory thinking, critical thinking and analysis, interpersonal relations and collaboration. Three reviewed studies present examples of how a blended design may support participative and research methods, that is, research activities based on professional practice (Sidebotham et al., 2014), problem-based learning with additional cognitive tools for documentation, presentation and argumentation (Tambouris et al., 2014), and social networking, tutoring and presentation to build content knowledge and a professional community of peers, so-called dialogic learning (Simpson, 2016). These blended course designs, to a greater or lesser extent, combine active knowledge acquisition embedded in the professional context, scaffolded practice and collaboration through participation and negotiation supported by a technologically enhanced learning environment. BL seems to have various possibilities to activate students' learning, but "sustainability learning requires seeking and cultivating learning environments that invite and enable people to envision alternative futures, experi¬ment with action, anticipate different outcomes, and learn from their attempts. All these processes combined help build transformative capacity, especially the capability of individuals and collectives to bring about fundamental change." (Wals, 2019, p. 71). This orientation towards change and action is missing in the BL practice studied and therefore in the derived design principles. Two examples demonstrate how technological enhancements may support transformation in knowledge, skills and attitudes of students towards sustainability problems, challenges and opportunities by increasing students' autonomy to direct their own learning. Sibbel (2014) describes the online development of students' knowledge management skills (capture, interpretation, integration and reconstruction), supported by face-to-face interactions, applied in cycles of collection and sharing, encouraging (peer) feedback and self-reflection to create awareness of personal attitudes and values. Archambault and Warren (Archambault & Warren, 2015) describe a blended course design for future educators, in which digital storytelling techniques are used to stimulate students' engagement and knowledge acquisition of sustainability issues, followed by in-class discussions on how the content can be implemented in their future classrooms. Both courses aim to bring about sustainable change in personal attitudes and

values for one (Sibbel, 2014), and professional practice for the other (Archambault & Warren, 2015). In both designs, in-class sessions were used for discussions. Critical thinking skills and in-depth exploration could have been encouraged if these synchronous discussions had been accompanied by asynchronous discussions online (Bliuc et al., 2011). To conclude, to emphasise transformative learning two design principles of BL should be adapted. Knowledge acquisition should not only be based on existing knowledge but also on constructing new knowledge contributing to sustainable change and while bringing this knowledge into practice the corresponding tasks should not only be authentic but also action-oriented.

The last design principle, collaboration for constructing a shared outcome through participation and negotiation with fellow students is a commonly used learning activity in BL to motivate students (RC5). Participative learning methods are also mentioned as appropriate methods for sustainability-oriented learning (Lambrechts, Mulà, Ceulemans, Molderez, & Gaeremynck, 2013; Lozano et al., 2019; Tejedor et al., 2019) because collaboration is a contingency to develop interpersonal competency (Wiek et al., 2011). As a key component of this competency, Wiek et al. (2011) mention "the capacity to understand, embrace, and facilitate diversity across cultures, social groups, communities, and individuals" (p. 211). A digital learning environment can easily facilitate this diversity in collaboration activities without having to travel, so at low costs (De Kraker et al., 2014). In sustainability-oriented education, interpersonal competency is connected to all other key competencies (Brundiers et al., 2021). To realise this, a collaborative approach should use the aforementioned disciplinary and cultural perspectives to address complex social, ecological, technical and other problems to bring about transformative change (Evans, 2015). The inter- or transdisciplinary way of collaborating is not mentioned in the review studies and should be integrated into the design principle. Table 4.6 contains the adapted design principles together with the recommendations from the realist review.

Table 4.6. Design principles for sustainability oriented BL. In italics: additions to support sustainability oriented learning. Context can be traced back in the context table (Appendix A)

Design principle	RC nr	Recommendations (RC) from the realist review
Aiming at self- regulation (and self-awareness) of learning and practice in the student's learning process	RC1	Students start their BL experience with different levels of self-regulation (Zhu et al., 2016) as well as dealing with the digital learning environment (Traver et al., 2014). Therefore, the organisation of the BL unit should be properly introduced to the students at the beginning (Traver et al., 2014). In addition, the communication about study and submission expectations should be clear throughout the learning unit (Lee, Jihyun & Choi, 2019; Traver et al., 2014; Xiu & Thompson, 2020; Zhu et al., 2016).
	RC2	The learning process of the student can be supported by the lecturer by delivering direct feedback on their performance (Tsai, 2014). Feedback can also be provided through online tests and quizzes (Cabrera et al., 2017). Online (formative) tests provide students with insights into their learning process and encourage the student to study regularly (Cabrera et al., 2017). Also, a digital learning environment using learning analytics can generate warnings to the students if they spend insufficient time on their work (Lee, Jihyun & Choi, 2019).
	RC3	To motivate students, the presence of the lecturer should be apparent throughout the BL unit in supporting the students, in class as well as online (Sidebotham et al., 2014; Tsai, 2014; Xiu et al., 2019).
	RC4	Give the students opportunities to compare their work with the work of fellow students. This increases motivation and positive competition (Saghafi et al., 2014).
	RC5	Motivation to spend a great deal of time on the required tasks increases when students are working in teams (Baranova et al., 2019; Evans, 2015; Tsai, 2014).
Fostering a safe and social learning environment	RC6	Organise at the beginning of the BL unit opportunities to get to know one another during an in-class meeting, because meeting online with new classmates is experienced as more difficult (Hall & Villareal, 2015).

Design principle	RC nr	Recommendations (RC) from the realist review
	RC7	Provide opportunities for students to interact with each other during in-class meetings to create an atmosphere of mutual attention and warmth (Sidebotham et al., 2014; Spadafora & Marini, 2018; Turula, 2018).
	RC8	Emotional closeness and personal ties among students can be promoted by creating opportunities for informal online interaction (social networking, blogs) (Lee, Jieun & Bonk, 2016; Wang, M., 2010).
	RC9	A lecturer may consider delivering complex feedback through a video recording to a student. This is conducive to a feeling of connection with the lecturer (Borup et al., 2014).
	RC10	The lecturer should monitor online discussion platforms to ensure that everyone's views are treated with respect (Hall & Villareal, 2015).
	RC11	Online collaboration can isolate some students, so, regularcoaching of a lecturer is necessary (Saghafi et al., 2014).
Facilitating (a)synchronous interaction and discussion among fellow students and with the lecturer to stimulate reflection and critical thinking.	RC12	Take different approaches to learning into account by providing the opportunity to discuss topics synchronously as well as asynchronously (Bliuc et al., 2011; Hall & Villareal, 2015).
	RC13	Provide clear instructions to online discussion boards to encourage meaningful responses (Hall & Villareal, 2015).
	RC14	The lecturer should consider if s/he delivers feedback synchronously or asynchronously to the student. Asynchronous delivery provides the student with the opportunity to consider the feedback given and to correct their work (Borup et al., 2014; Turula, 2018). In addition, through asynchronous online tutoring students reach higher levels of critical thinking due to having more time to process the student-tutor exchanges (Turula, 2018). Synchronous face-to-face tutoring may result in a dialogue in which a student gets the opportunity to develop communication skills (Simpson, 2016).
	RC15	Provide an online collaboration environment for social and task-oriented interaction, thus, organizing discussions and documenting the process (Lee, Jieun & Bonk, 2016; Northey et al., 2015; Tambouris et al., 2014).

Design principle	RC nr	Recommendations (RC) from the realist review
Transforming learning through acquisition and inquiry into an active process based on existing knowledge (in which new knowledge is constructed to contribute to sustainability)	RC16	Support students' preferred learning strategies by providing different representations of online content, for instance, a video lecture, an interactive online textbook or a podcast. Videos should be short with attention-grabbing audio and visual components (Hall & Villareal, 2015; le Roux & Nagel, 2018; McLean et al., 2016; Xiu et al., 2019).
	RC17	Embed the topic of the course in the own experiences of students and contextualise it to real-life situations to stimulate participation in the learning activity (Cardak & Selvi, 2016; Sidebotham et al., 2014).
	RC18	Offer, in a flipped approach, not only video recordings of lectures but also organise opportunities for students to verify their understanding of the concepts (online tests, Q&A) (Brewer & Movahedazarhouligh, 2019; le Roux & Nagel, 2018; McLean et al., 2016; Xiu et al., 2019). In addition, the in-class meeting could be started with a quiz and a review of the topics covered (Akkaraju, 2016).
Working on authentic (and action-oriented) tasks with scaffolded and theory-based practice meeting the learning preferences of students	RC19	To encourage students to work on their tasks, give students a choice between different assignments to meet their learning preferences (Cardak & Selvi, 2016; Cheng & Chau, 2016).
	RC20	Provide for assignments containing formative intrinsic feedback (tests, video, FAQ). This reduces anxiety and provides extra practice (Hall & Villareal, 2015).
	RC21	In design studio education, a physical classroom facilitates the exchange of ideas, practice and learning of fellow students and a virtual classroom, reflection on the process and, asynchronously, researching new concepts (Saghafi et al., 2014).
	RC22	Give in preparation for a laboratory class an online simulation product or video. Students can build self-confidence in their knowledge and abilities and increased engagement (Deegan et al., 2016; Son, 2016).
(Inter/transdisciplinary) Collaboration for constructing a shared outcome through participation and negotiation with fellow students in a technologically enhanced learning environment	RC23	Mix students with a surface and a deep approach to learning so that all collaborative groups have at least one or two stronger partners (Han & Ellis, 2020).
	RC24	The digital learning environment should support collaboration, that is, support of interaction and project organisation as well as documentation (Tambouris et al., 2014; Vaughan, 2010).

4.5 Discussion and suggestions for future research

Key design principles and associated recommendations have been developed to guide the design process of a BL unit supportive to develop students' sustainability competencies. As a first step, design principles and recommendations were extracted from the BL practice in general, answering the first research question. Similarities and differences have been unravelled by mirroring these principles against sustainability competencies and the corresponding pedagogical approach, corresponding to the second research question. This section discusses the most important features of these design principles as a result of answering the two research questions and, if relevant, accompanied with directions for further research.

At first glance, the guiding principles seem to be rather generic and relevant for higher education in general, but the given directions are crucial in BL and they can also be valuable in informing sustainability-oriented education, because self-regulation, community building, interaction and discussion, knowledge management and collaboration have been identified as critical in students' learning around wicked sustainability problems (De Kraker et al., 2014; Lambrechts et al., 2013; Lozano et al., 2019; Tejedor et al., 2019). In a high-quality BL design, the added virtual space can enhance sustainability-oriented learning by enabling self-directed learning, (a)synchronicity in time and place-independency. Regarding self-directed learning, digital technology can engage an individual student in acquiring (reliable) knowledge and understanding of sustainability issues through multimedia content delivery (Archambault & Warren, 2015) and tools for feedback and assessment (Sibbel, 2014). Making use of the advantages of (a)synchronicity in time enhances the reflection and critical thinking skills of students (Bliuc et al., 2011; Simpson, 2016; Sivapalan, 2017; Turula, 2018). And lastly, place-independency creates possibilities to facilitate incorporating different disciplinary, cultural and social perspectives in collaboration activities (De Kraker et al., 2014). This inter- or transdisciplinary approach of collaboration could be one of the affordances of BL, but it represents also one of the omissions in the BL practice studied. Further research is needed on how inter- or transdisciplinary collaboration can reach its full potential in a blended design.

Although all design principles are essential, one principle in particular requires more attention and that is Fostering a safe and social learning environment. The forced online learning modus during the COVID-19 pandemic has led to a negative impact on students' performance and well-being (Acosta-Gonzaga & Ruiz-Ledesma, 2022; Raccanello et al., 2022). Several academic studies have studied this impact. A search in Google Scholar with the search term "emotional well-being COVID-19 online learning "higher education" resulted in 44,600 hits (accessed 24 Feb. 2023). The emotional well-being of students has not been explicitly included in Fostering a safe and social learning environment and probably a study of the aforementioned post-COVID-19 studies can add recommendations to fill this gap.

Transformation to a sustainable world needs 'change agents', who are aware of what they can or want to change and know how to take action for implementation (Brundiers et al., 2021). Two

BL designs demonstrate how this can be done (Archambault & Warren, 2015; Sibbel, 2014), but it is not common practice in a BL design. To create this self-awareness and transformative capacity action-oriented methods are supportive, such as environmental place-based learning and community-oriented service learning. Opportunities to facilitate this by BL probably lie in creating value for the local community (Powers, A. L., 2004) or experiencing the surroundings through a virtual augmented reality platform (Zhao & Klippel, 2019). This could also be employed as a preparation or follow-up activity for a field trip (Merritt, Stern, Powell, & Frensley, 2022). Further research into these opportunities is recommended.

Although the aforementioned Integrative Relational Framework, a term we coined to describe the theoretical vantage point provided by Ellis and Goodyear (2013), seems to align well with recent work on sustainability-oriented learning (Wals, 2019), this perspective did not surface prominently in the papers reviewed. Therefore, some additions to the design principles have been proposed and the integral utilization of these guiding principles might well lead to a more ecological or relational perspective on educational design in higher education, especially in universities seeking to become more relevant, responsive and responsible in light of current and emerging global challenges.

Lastly, a high-quality ecological BL design can also help HEIs in walking the talk in reducing a part of their travel-related carbon footprint. While this seems somewhat disconnected from this study, this is an essential aspect of a whole institution approach to sustainability (Kohl et al., 2021), where universities need to become living practices of sustainability.

Research limitations

A single researcher conducted the collection and analysis of data by applying a realist review methodology. It is possible that alternative decisions would have been made if another researcher had been involved or if a team of researchers had collaborated to reach a joint consensus. However, the subjective nature of decision-making was mitigated by the iterative process of our realist approach, which compelled the researcher to repeatedly re-evaluate previous choices across multiple stages. The review protocol itself and the interpretation of the data were discussed in regular sessions with others.

The aim of the realist review, to explore 'what works for whom, in what circumstances, in what respects, and how', cannot be met for all that is possible with BL. Therefore we applied a pragmatic approach. The initial design principles are not evaluated in the empirical evidence as a whole but in parts. It provided an overall picture of the focus areas in BL and how they are dealt with in practice. To validate the effectiveness of the complete set of pedagogical design principles in a blended design, more research is needed.

There is a plethora of research available about BL. In this research, 38 studies are used after an extensive search in multiple libraries, but inevitably, interesting studies on the subject have been overlooked, especially those not published in the selected databases, including studies published in other languages than English.

Although all design principles are essential, one needs more attention and that is Fostering

a safe and social learning environment. The forced online learning modus during COVID-19 has led to a negative impact on students' performance and well-being (Raccanello et al., 2022). Several academic studies have researched this impact. A search in Google Scholar with the search term "emotional well-being COVID-19 online learning "higher education" resulted in 44,600 hits (accessed 24 Feb. 2023). The emotional well-being of students has not been explicitly included in Fostering a safe and social learning environment and probably the aforementioned post-COVID-19 studies can add recommendations to fill this gap.

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Appendix A

Table A1. Context of the empirical studies about a BL intervention

Reference	Participants (Average) age	Study phase	Subject	Didactic method
(Baranova et al., 2019)		undergraduate	English, International Business	Flipped learning, project-based learning
(Borup et al., 2014)			Technology integration courses	Video feedback
(Cabrera et al., 2017)			Engineering,	
				learning/online web communities
(Cardak & Selvi, 2016)			Education Program of Elementary Education	In-class learning + online activities like virtual class, forum, blog page
(Deegan et al., 2016)	19		Practical skills training for agricultural education	Virtual and physical lab
(Enneking et al., 2019)		First-year	Introductory chemistry	Virtual and physical lab
(Lazinski, 2017)		First-year	Laboratory course	In-class + online activities like instructional or self-video, peer feedback, blog
(le Roux & Nagel,		Third year	Entrepreneurship	Flipped learning,
2018)			course	group project
(Mese & Dursun, 2019)	19	First-year	Information Technology	gamification
(Quinn & Aarao, 2020)		First-year	Mathematical Methods for Engineers	Choice of amount of blending, supported by videos and interactive and communication tools
(Sivapalan, 2017)	19-21	Undergraduate	Communication and presentation skills	Flipped learning, video-based lectures, in-class discussions followed by online discussions of sustainability topics via Facebook
(Son, 2016)	23.4	Undergraduate	Biology	Physical and virtual lab
(Spadafora & Marini, 2018)	20-22	Fourth year	Child and Youth capstone course	Interrelated academic activities ranging from analysing video-based material to reading research papers

Reference	Participants (Average) age	Study phase	Subject	Didactic method
(Traver et al., 2014)			17 blended courses	Blend: 20 to 80% weekly class time conducted online
(Turula, 2018)			Writing and defending thesis	Blended tutoring
(Vaughan, 2010)	Third year		Experimental Psycholinguistics	In-class learning combined with collaboration activities supported by Web 2.0 technologies
(Zhu et al., 2016)	Second-year		ICT in teaching and learning	In-class learning + online activities like assignments and forum
(McLean et al., 2016)	Undergraduate		Medical Sciences	Flipped learning: online modules with quizzes to be completed before in-class session
(Xiu et al., 2019)	First-/second year		Biology	Video lectures with guiding questions and quizzes + in-class learning + physical lab
(Akkaraju, 2016)			cardiovascular physiology	Flipped learning: online learning modules assessed at the beginning of in-class session (problem solving assignments)
(Brewer & Movahedazarhouligh, 2019)	19-45		Special education	Flipped learning: online videos, in- class discussions, group projects
(Xiu & Thompson, 2020)	21.5	11.9% sophomores, 35.6% juniors, and 50.8% seniors	Hospitality management, leisure services	Flipped learning: online textbook with Powerpoint, in-class group work and discussion
(Lee, Jihyun & Choi, 2019)		Juniors and sophomores	Life science	Flipped learning: online videos and documents assessed at the beginning of in- class session (discussion)
(Tsai, 2014)	20	Second-year	Building business-quality websites	Collaborative learning
(Bliuc et al., 2011)		Third year	Social sciences course	Discussion in-class and online

Reference	Participants (Average) age	Study phase	Subject	Didactic method
(Wang, M., 2010)		First-year	English	Collaborative communication. Discussion groups
(Hall & Villareal, 2015)			hybrid courses	Online: lectures and assignments for diverse learning styles, in- class discussion and collaboration
(Sidebotham et al., 2014)		First-year	Research, Evidence and Clinical Practice	Experiential situational learning, research
(Simpson, 2016)		Fourth-year	Education	Dialogic learning
(Cheng & Chau, 2016)		Sophomores	Digital Citizenship	Online activities according to student's learning style
(Saghafi et al., 2014)		Third-year	Architecture course design	Virtual design studio and in-class activities
(Bolsen et al., 2016)		Graduate	Introduction to American Government	Interactive online textbook
(Tambouris et al., 2014)	23-28	Post-graduate	Project management	Problem-based learning
(Powers, K. L. et al., 2016)		First-year	Introductory Psychology	Textbook + virtual lab
(Adams, Randall, & Traustadóttir, 2015)		All years	Introductory Microbiology	Flipped learning: online lectures assessed at the beginning of an in- class session
(Northey et al., 2015)		Undergraduate	Marketing course	In-class sessions complemented by asynchronous discussions using Facebook
(Han & Ellis, 2020)		First-year	Introduction to human biology	Teamwork
(Lee, Jieun & Bonk, 2016)	24-45		Understanding and Utilizing Web 2.0 Tools for Education	Blended learning using blogs for interaction and reflection

CHAPTER 5 Design and evaluation of a sustainable blended study programme

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Abstract

Blended learning, i.e. a mix of online and in-class education, can be deployed for enhancing the educational quality and resilience in higher education (HE). It may also contribute to HE's sustainability objectives by lowering the carbon emissions of students commuting to campus. In this study, pedagogical design principles for sustainable blended learning and teaching are developed and evaluated taking into account these opportunities. A prototype for a sustainable blended study programme at a University of Applied Sciences was developed and evaluated using a form of Educational Design Research. The design stage, carried out by a team of eight lecturers, resulted in a design based on six pedagogical design principles. This design also included an effort to reduce student travel by limiting on-campus education to two days a week. The results show the effects of students' increased online learning skills and diminished travel movements on their satisfaction with the blended learning design, and their travel behaviour, which can lead towards an attitude change regarding commute and online learning. The lecturers' observations and experiences, depending on their personal preferences, contradicted (self-regulation skills) as well as confirmed (online learning experiences) the students' evaluations.

5.1 introduction

Higher Education (HE) has a key responsibility in addressing the grand sustainability challenges of our time through forms of responsible research and education (Tassone et al., 2018). Colleges and universities are looking for ways to reduce their own carbon footprints and climate impact (Helmers, Chang, & Dauwels, 2021; Valls-Val & Bovea, 2021) as well as taking measures for adaptation to mitigate the impact of natural disasters (Mackey et al., 2012). During the COVID-19 pandemic, most higher educational institutions (HEIs) (67 %) made a rapid transition to, so-called, emergency remote teaching (Marinoni et al., 2020). Research into the impact of this transition on the academic community in the United Kingdom showed, "a history of professional dysfunction and disturbance (...)." (Watermeyer, Crick, Knight, & Goodall, 2021, p. 638). This was, at least in part, due to deficiencies in existing infrastructure and the availability of devices for online/distance learning, and teacher training (Marinoni et al., 2020; UNESCO, 2021). Before the COVID-19 pandemic, HE showed a reluctant attitude toward using online learning (Versteijlen et al., 2017) but experiencing not only the disruptive transition but also the opportunities of online learning seems to change this attitude in one of interest (Ntim et al., 2021). Therefore, a blended learning design, allowing for both on and offline forms of instruction and learning, seems to be the way forward but careful thought must be given to how to take advantage of these opportunities, including its potential to contribute to sustainability by lowering the carbon emissions of students commuting to campus (Versteijlen et al., 2017). In HE, a large number of students travel by car or public transport to attend learning activities at their institution (Ozawa-Meida et al., 2013). According to Caird et al. (2015), distance-based HE teaching models (distance, online) achieve carbon reductions of 83 per cent in comparison with on-campus models (in-class, ICT-enhanced), largely due to student commuting (Caird et al., 2015). When designing a blended learning configuration that may have a mitigating effect on carbon emissions by decreasing students' travel movements, the considerations underlying their decision to make a trip to campus should be considered. It seems that students make reasoned choices that depend on their attitude toward the learning activities they are supposed to attend in line with the Theory of Planned Behaviour (Ajzen & Madden, 1986; Hollett et al., 2020; Versteijlen, van Wee, & Wals, 2021). According to the Theory of Planned Behaviour (Ajzen, 1991), the student's choice to make a trip to campus derives from an intention depending on attitude, social norms and perceived behavioural control Attitude is determined by their evaluation of the type of learning activity, the lecturer and their interest in the topic, and also, by social norms and their own perceived learning abilities (Versteijlen et al., 2021). An online learning opportunity can be an alternative option to consider. During the COVID-19 pandemic, students experienced the effects of the transition to emergency remote teaching, probably affecting their attitude towards online learning and commuting to the HEI. Van Wee et al. (2019) assume that such a trigger may cause an attitude change in what students know, feel or do. They distinguish three processes, leading to this attitude change, that is, cognitive, behavioural and affective processes (Van

Wee, De Vos, & Maat, 2019). Applying this theory, the online learning experiences during the COVID-19 pandemic increased a student's knowledge about online learning advantages. These experiences (behavioural process) and increased knowledge (cognitive process) may affect their satisfaction with this type of learning (affective process). When this causes an attitude change towards online learning, it may lead to different choices regarding travelling to campus for attending in-class sessions. This study conducted an initial exploration of this potential attitude change as a result of the COVID-19 pandemic.

While there seem to be benefits of blended learning in realizing both resilience and a lower carbon footprint, which many HEIs aspire to, a key assumption is that a blended learning study programme should maintain, or ideally improve, educational quality. When considering this educational quality in terms of realisation of the learning outcomes, student satisfaction and engagement, several empirical blended learning studies show positive results (Baranova et al., 2019; Cabrera et al., 2017; Lazinski, 2017; Quinn & Aarao, 2020; Vaughan, 2010) . Still, a blended learning design is not in and by itself a guarantee for good education. Education is complex and influenced by different contextual factors. Nortvig et al.(2018) concluded, that not the blended or online design is a determinant for good education but factors such as, "educator presence in online settings, interactions between students, teachers and content, and deliberate connections between online and offline activities and between campus-related and practice-related activities" (Nortvig et al., 2018, p. 53). It seems to be essential to design blended learning carefully (Laurillard, 2013), needing a pedagogical approach that acknowledges that blended learning is more than a fusion of online and in-class learning and teaching (Bliuc et al., 2011; Garrison & Vaughan, 2008; Vaughan, 2007). Nevertheless, a detailed framework for how to design blended learning does not exist (Boelens et al., 2017). This study intends to contribute to filling this gap.

This research aims at finding directions how to lower the environmental impact of a study programme without compromising educational quality. This aim is realized by developing and evaluating pedagogical design principles for, what we will call, a sustainable blended learning study programme and to evaluate students' travel behaviour as a result. The term 'sustainable' points to an efficient educational organisation that reduces student commute to and from campus to two days per week while not compromising educational quality. This objective contributes to realizing Sustainable Development Goal (SDG) 13, which calls for urgent action to combat climate change, and SDG 4, which focuses on creating quality education for all. SDG 4 and 13 are part of the 2030 Agenda for Sustainable Development, adopted by 194 countries in 2015 (United Nations, 2015).

Since government restrictions due to the COVID-19 pandemic changed the blend to mainly online education, we included in the objective whether indicators could be found that experiencing mainly online learning might influence the student's attitude toward online learning and educational travel. To the best of our knowledge, this is the first empirical study to present the results of developing pedagogical design principles during the design and implementation of a sustainable blended learning study programme that not only

considers pedagogical issues but also the associated student travel behaviour. By establishing an empirical foundation, this study lays the groundwork for broader application and the advancement of knowledge in future implementations.
This objective is achieved by answering the following research questions:
RQ1. How did the design team experience developing a sustainable blended learning study programme grounded in pedagogical design principles extracted from academic theory?
RQ2. How do students and lecturers evaluate learning and teaching during the implementation of the blended learning design?
RQ3. What cognitive, affective and behavioural processes can be observed while experiencing online learning, due to COVID-19 restrictions, that could lead to an attitude change in students toward educational travel and online learning?

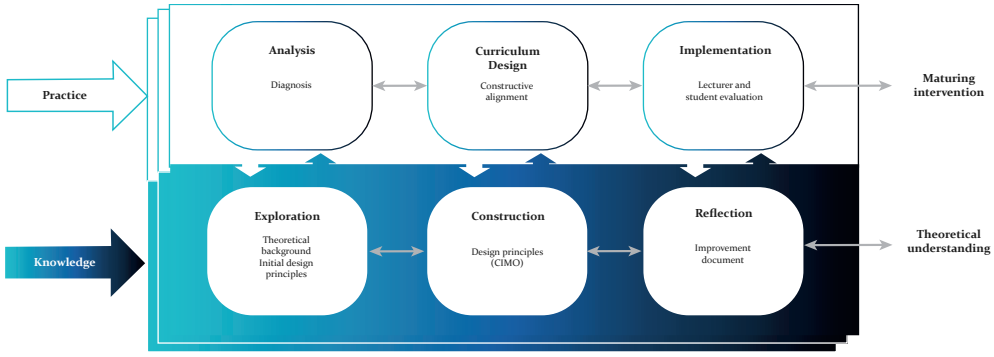
Section 5.2 first introduces the methodology used to answer the research questions, followed by Section 5.3 presenting the results. Finally, Section 5.4 discusses the findings, to finish with the main conclusions.

5.2 Methodology

The chosen approach to study the development and implementation of sustainable blended learning and teaching is the Educational Design Research (EDR) approach. The term "Educational Design Research" was coined by McKenney and Reeves (2018). It incorporates the term 'education' to avoid confusion with design research from other fields (McKenney and Reeves, 2018). In EDR, solutions to complex real-world problems are sought and, by iteratively examining them in multiple contexts, theoretical knowledge emerges (McKenney & Reeves, 2018). We chose this methodology because of its strong connection to educational practice, contributing to more practical relevance (Van den Akker et al., 2006). In addition, design-based research recognizes and meets the complexity of an intervention such as the transition to blended learning and teaching. This complexity is caused by the various context variables that determine this intervention's outcome, for instance, the actions of designers, lecturers and students with their own intentions and motivations or the system policy of an HEI. In addition, EDR assumes that education evolves over time. Several iterations of research, development, testing and refinement in different contexts shape the resulting practical solution and theoretical understanding (Van den Akker et al., 2006).
In this exploratory study, we designed and evaluated one case or prototype of a sustainable blended learning unit. Our model (Figure 5.1), based on the generic educational design-based research model of McKenney and Reeves (2018), shows three main stages in which the knowledge stream leads to theoretical understanding and the practice stream to a maturing intervention. The bi-directional arrows indicate that the process is iterative and flexible. RQ1

is answered in the stage 'Curriculum Design and Construction', and RQ2 and RQ3 in the stage 'Implementation and Reflection'.

Figure 5.1. Educational design based research model. Based on: (McKenney and Reeves, 2018)



Analysis and Exploration

During the analysis stage, we thoroughly explored opportunities for blended learning involving various stakeholders. In the first exploration (Versteijlen et al., 2017), educational professionals (lecturers, managers and ICT service providers) of different Dutch HEIs were interviewed about the potential of online learning to decrease student travel. In the second exploration (Versteijlen et al., 2021), student travel behaviour and its connection to their learning activities were studied from the perspective of students. The findings of these two studies together with a literature review resulted in an initial draft of the design principles for sustainable blended learning. In addition, the Conversational Framework of Laurillard (2009) inspired these initial principles. This framework considers learning as an iterative process (reflection, feedback, clarification loops), linking both theory and practice, engaging students, teachers and fellow students (Laurillard, 2009).

The initial principles were tested and refined during the design and implementation of an economic business minor at Avans University of Applied Sciences (Avans UAS). A minor is a one-semester study programme on a specific subject, aimed at either broadening or deepening the study. This minor 'Public Controlling' focuses on the position of the public controller in public and non-profit organisations. The previous minor was outdated and the lecturers opted for a full redesign to a blended curriculum.

Curriculum Design and Construction

A team of eight educational practitioners with different backgrounds designed the minor from November 2019 to June 2020 in monthly sessions of approximately six hours. The team consisted of five content experts, that is, a minor coordinator, an educational expert and two educational ICT experts. The researcher (first author) was present at most sessions.

The minor's curriculum was designed according to the principles of constructive alignment,

in which "the intended outcomes of teaching need to be stated upfront, and teaching methods and assessments need to be aligned to what those outcomes require if they are to be met" (Biggs & Tang, 2020,p. 24).

To create a prototype, the ABC curriculum design method (Young & Perović, 2016) was used in a rapid-development workshop. The corresponding card set is based on the six learning types developed by Laurillard (2013), that is, acquisition, inquiry, practice, production, discussion and collaboration. The initial design principles were partly based on the Conversational Framework of Laurillard (2013) (Section Analysis and Exploration), ensuring a proper alignment between curriculum design and design principles.

During this stage, the initial design principles were further developed in dialogue with the design team. In support of this team, each principle was supplemented with context, interventions (learning activities), mechanisms that may be triggered by the interventions mentioned, and potential outcomes (extracted from academic literature). The interventions were divided between on-campus and online activities. This structure is based on CIMO logic (Context, Intervention, Mechanism, Outcome) (Denyer et al., 2008).

The design and construction phase was evaluated in June 2020 by interviewing three members of the design team, namely the coordinator, a content expert and an ICT expert. The recordings of the interviews were transcribed and analysed using Atlas.ti qualitative analysis software (version 8).

Evaluation and Reflection

The minor was held from September 2020 to January 2021 and started with 26 fourth-year students of which two students quit for personal reasons. All students were between 19 and 25 years old. Nineteen students lived at their parent's homes within travelling distance from campus (Figure 5.2). Four minor students were enrolled originating from other colleges. The three minor lecturers were design team members. Because of the COVID-19 restrictions, on-campus education was diminished to half a day per two weeks supplemented with online activities, instead of the planned 1 or 1.5 days per week. Halfway the minor on until the end only online education was possible.

The perceptions of lecturers as well as students are incorporated in this evaluation. All three lecturers are interviewed two months after the minor. They were interviewed about their experiences with the interventions associated with the design principles during a 60-minute interview with each of them. Also, some general questions were asked about strengths, challenges and possible improvements of this blended minor. The recordings of these interviews were transcribed and analysed using Atlas.ti qualitative analysis software (version 9).

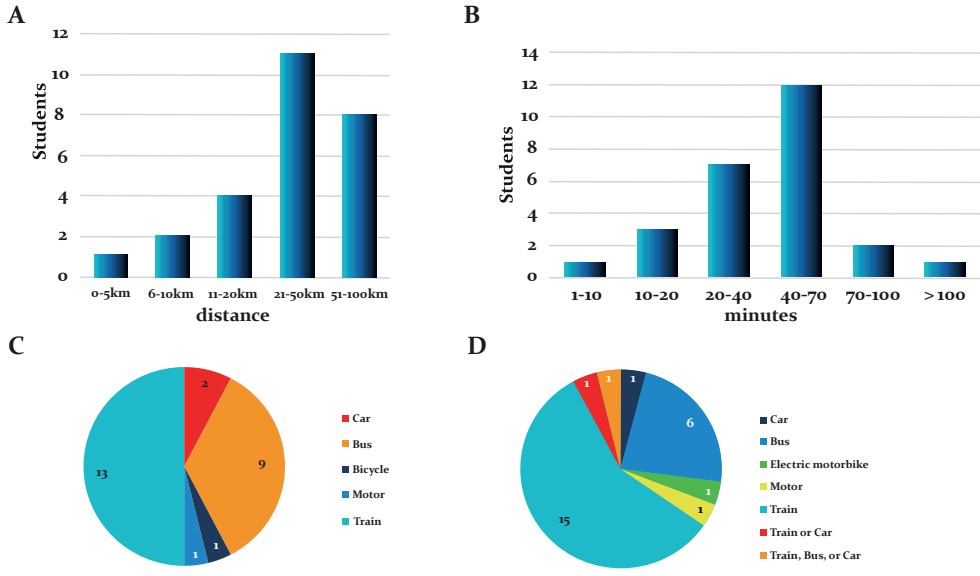


Figure 5.2. Demographic data extracted from the baseline measurement survey. A. Distance from home to campus assuming the fastest road route. B. Travel time during minor. C. Travel mode of students (greatest distance, when using more than one travel mode) before the COVID 19 pandemic. D. Intended travel mode of students (greatest distance)

The students' experiences are evaluated using a mixed research approach (Figure 5.3). The mixed approach is selected to enable triangulation, allowing for the verification of the in-depth observations of some students within the entire group (Creswell & Clark, 2017). In addition, a potentially changed attitude toward online learning and commuting after COVID-19 is quantitatively measured at the start because this may influence their evaluation of the blended design. For the quantitative research, the students completed two surveys with Microsoft Forms. The results are analysed with descriptive statistics techniques using IBM SPSS Statistics 28 software. Likert scales (Strongly Disagree, Disagree, Undecided, Agree, Strongly Agree) are applied to measure students' opinions. These categories are converted to numeric values 1 (strongly disagree) to 5 (strongly agree) in order to analyse the data using mean, mode and standard deviation. Other variables were measured on a nominal level, e.g. living conditions, and on a continuous level, e.g. travel time. The baseline measurement survey contains questions aiming at finding indicators about an attitude change of students towards travel choices to college or type of learning The questions are based on the study on attitude change (Van Wee et al., 2019) and the study on student travel behaviour (Versteijlen et al. , 2021), both introduced in the section Introduction. The survey questions of the final measurement were based on the results of the qualitative research (two focus groups), the Community of Inquiry Survey Instrument (draft v14) (Arbaugh et al., 2008) and the student survey questionnaire of Garrison and Vaughan (2008). These questions were divided into categories and in each category, students could add a comment on their answers. Categories,

associated variables and measurement details of the surveys can be found in Appendix A and B.

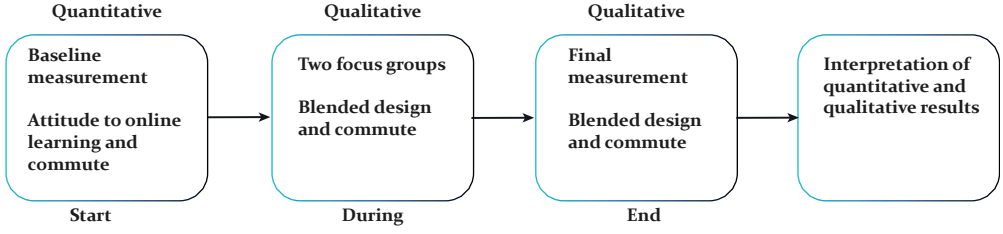
For the qualitative research, we organised two focus groups. In focus groups, students interact with each other and discuss their views and are thus well suited for gaining insight into their thoughts and beliefs (Stewart & Shamdasani, 2014). One focus group consisted of four male students and was organised online. The other consisted of six students (five male, one female) and took place on campus. There was no special reason to do so other than scheduling issues. The focus group meetings were led by the researcher (first author), who had no relationship with the students. Audio and video recordings were made during the session. At the beginning of the meeting, the students were asked to fill in a consent form and to provide some personal data: name, date of birth, gender, original study location, and travel mode(s) to college. They were assured that all their statements were to be treated confidentially.

The interview guide contained all the questions divided into different topics. These topics are travelling from and to the college, travelling to non-study activities and the implementation of each of the design principles. The first two topics about travel are follow-up questions to the answers given in the baseline measurement survey. The other six topics aim to establish how the students perceive the applied design principles.

The recordings of the sessions were transcribed and analysed using Atlas.ti qualitative analysis software (version 8).

All transcriptions of the qualitative data (focus groups and interviews) were analysed using the scissor-and-sort method (Stewart and Shamdasani, 2014). Fragments of text relevant to the research questions were identified and coded. These codes were ordered into code groups and assigned to categories. These categories are learning process, feedback, community feeling, interaction, discussion, acquisition, practice, collaboration, teaching, and travel. The results are incorporated into an evaluation document in which per category quotes of students and lecturers are paraphrased, supplemented with corresponding results from the surveys. Each paraphrase has a code referring to the text fragment. This evaluation document was meant for the lecturers to improve the design of the study programme.

Figure 5.3. The mixed research approach to evaluating student perceptions



5.3 Results

The results are described according to the research questions (RQ). In Section The blended minor development, the design team's experiences of the process, academic support and the resulting design are presented (RQ1). The implementation of this design is evaluated according to the design principles in Section Evaluating the implementation of the blended learning design (RQ2). Section Possible attitude change toward educational travel and online learning shows what attitude change towards educational travel and online learning could be observed among the minor students (RQ3).

The blended minor development

The design process followed the principles of constructive alignment where the designers begin by determining the learning goals and the associated assessments. They consulted several public sector professionals to get input for establishing learning goals. The three interviewed designers were satisfied with the concept of constructive alignment but they experienced that learning goals, assessments, and (blended) learning activities influence each other and a more iterative approach might have been more productive.

By the time, online and in-class learning activities could be added to the design, the ABC method was used in a rapid-development workshop to create a prototype (Figure 5.4). The facilitator remarked about this workshop:

> *"At first, with the maps and the posters, as they were intended, I noticed a lot of resistance. But perhaps that depended more on the kind of persons than on the model. The team members just wanted to build the minor and this felt like a kind of unnecessary intermediate step".*

The team members thought this ABC method was too complicated and theoretical. Nevertheless, they all admitted that, after depicting the results in an Excel sheet, it was useful in a later stadium. During the sessions, the researcher observed (and this was confirmed by the ICT expert), that the designers focussed more on the design of in-class learning than on the non-scheduled online activities. The reason is the allocation of the lecturer load hours. The used workload model, based on traditional face-to-face education, is not suitable for allocating unscheduled online activities. The blended minor development was supported by the creation of design principles for blended learning extracted from academic literature. The initial design principles evolved throughout the design process and resulted in design principles structured according to CIMO logic (Denyer et al., 2008) (Appendix C). This structuring is used, because it provided the design team with concrete implementation

Figure 5.4. ABC method in action during a team session on March 23 th 2020

possibilities to meet these principles, provoked mechanisms and possible outcomes included. The design team used these principles to check the design, inspire ideas for learning activities and underpin the design choices made. The six design principles are:

1. Aiming at self-regulation in a student's learning process.
2. Fostering a sense of community.
3. Facilitating interaction and discussion among fellow students and with the lecturer.
4. Activating knowledge transfer.
5. Offering authentic, scaffolded and theory-based practice.
6. Collaborating for constructing a shared outcome through participation and negotiation with fellow students.

Due to COVID-19 restrictions, the online and in-class learning ratio was altered. The intention was to allocate 1.5 days per week for in-class learning activities. This became 0.5 days per two weeks. Nevertheless, the designers showed contentment with the resulting design but also reservations. The ICT expert commented on the non-scheduled online interventions in the design, depending on the lecturer and are not covered in the design. The coordinator and content expert showed concerns about theoretical knowledge acquisition. In the design, this depends on a student's willingness to study the literature offered. Table 5.1 depicts an overview of the learning activities with associated design principles, environment and frequency.

Table 5.1. Overview of the learning activities of the designed study programme. The numbers of design principles correspond to the list of design principles in Section The blended minor development.

Learning activity	**Associated design** principle	**Environment**	**Frequency**
Introductory session	2	Online	Once
Meetings with team and tutor	1, 2, 3, 5, 6	Online or in-class	Weekly
Guest lectures	4	Online or in-class	Weekly
Workshops fellow students	4	In-class	Once per student team
Research (literature and interviews)	4, 5	Mostly online	When necessary
Peer support	1	In Teams, Comproved FeedbackFruits	
Discussion	3	In-class	4
Workshop critical thinking and integrity	4, 5	In-class and online	2

Evaluating the implementation of the blended learning design

The perceptions of the lecturers and the participating students of the minor are discussed according to the design principles and associated learning activities. The names of the students are not their real names. The lecturers are referred to as L1, L2 and L3.

Aiming at self-regulation in a student's learning process

Students with self-regulation skills are capable to manage their time, structure their environment, set their goals and assess their progress in attaining those goals. To be able to do so, students need to know what is expected and how they perform during the learning process. To inform the students, a study manual was available with per learning objective, explanatory text, deliverables, learning activities and a schedule over the weeks. In addition, an introductory online session was held on the minor's first day, utilizing the results of a questionnaire in which students were asked about their interests, motivation, objectives and knowledge about public controlling issues. Students' performance was monitored during weekly team meetings (online and on-campus) with a lecturer present. Feedback on their progress with the assignment was provided twice per learning objective by the lecturer and also, by fellow students, using FeedBackFruits and Comproved (online tools which streamline self -, peer - and lecturer feedback).

Although the planning of activities was clearly stated in the study manual, changes due to COVID-19 occasionally confused students. The schedule, manual and rescheduling announcements contradicted each other (Table 5.2A). Still, it did not interfere much with their ability to plan their learning activities (Table 5.2C). Most students appreciated the extensive

possibilities to study anywhere, anytime (Table 5.2B). Some students found it difficult to concentrate during online lectures (Table 5.2D-E).

Table 5.2. Self-regulation data from the final measurement survey

		(A) During the minor, there was clear communication about important deadlines and time schedules for learning activities	(B) I appreciated the extensive possibilities to study anywhere, anytime	(C) I had no trouble managing my own time and I submitted my assignments on time	(D) I could concentrate well during the online guest lectures	(E) I could concentrate well during the physical guest lectures
N	Valid	17	17	17	17	17
	Missing	0	0	0	0	0
Mean		3.12	4.24	3.88	3.35	4.06
Mode		4	4	4	4	4
Std. Deviation		.857	.562	.857	.702	.429

Students (82%) were satisfied with the amount of feedback on their learning performance, especially the feedback from their lecturers during the team meetings. They had mixed feelings about the feedback from fellow students. Two observations from the focus group sessions:

> *"Sometimes I felt the feedback from fellow students a bit confusing because one said A and the other one B, which were exactly contradictory, so, then I wonder, what to do?"* (Finn)

and

> *"Sometimes you get feedback that is really useless or very superficial. Sometimes it is very good"* (Seth).

The lecturers confirm the observation of the students that the students' feedback on each other was of varying quality. A helping feature of the online feedback tool was that the lecturer could see how much time a student had spent on giving feedback.
During the online meetings, lecturers' opinions were divided on coaching the students. L1 stated that feedback during physical team meetings seems to be more effective than during online meetings because you can see the student's body language. L2 likes, when necessary, the opportunity to easily arrange an individual online meeting with a student right after the team session. L3 could extract sufficient information from the online meetings to address

undesirable behaviour and inadequate performance of students. Still, L3 also admitted to having little control over the students on days with no scheduled learning activities. L2 observes that one team did not immerse themselves in the literature given and therefore performed less well carrying out assignments.

> *"I didn't expect that students would not read those articles. I didn't expect that students would not discuss anything with each other. It was really a team containing five not-very-critical students. I had this other team containing four very critical students, so they did everything like a rock." (L2)*

Fostering a sense of community

In a blended learning situation with less physical contact, it is a challenge to create an atmosphere among students safe to deliver feedback or express views. To foster a safe and social learning climate some provisions were made in the design of the minor. Students collaborated in teams of four or five members. They communicated using an online platform (Microsoft Teams) and there were weekly team meetings with the lecturer (online and physical).

Most students appreciated the learning climate within the minor (Table 5.3B) and they felt safe expressing dissenting views (Table 5.3C). The blended design with physical and online meetings seems to be conducive to creating this atmosphere (Table 5.3A,D).

Table 5.3. Safe and social learning climate data from the final measurement survey

		(A) I needed the physical meeting to get acquainted with fellow students and lecturers	(B) Getting to know my fellow students gave me a sense of belonging	(C) Expressing a different opinion did not harm the bond of trust with fellow students	(D) The Teams meetings created a bond of trust within our group
N	Valid	17	17	17	17
	Missing	0	0	0	0
Mean		3.12	3.71	3.71	3.35
Mode		4	4	4	4
Std. Deviation		1.269	.470	.772	.786

When working in a team, most students did not experience the getting-to-know process in an online surrounding as different from a physical one. Tom stated:

> *"Yes, I think it is basically the same as at college, working in a team. I think you also get to know your team online. And besides that, you already know some people and about the new team members, in other years, you only started to know them when you joined them in some team".*

Although, Luke stated that

> *"I get to know a lot more about someone when meeting in real life".*

Outside their team, it is difficult to get acquainted. Finn stated,

> *"When you attend an online guest lecture, it says in a corner: there are 19 people present and I have no idea who they all are".*

Little was done to create a community feeling in the whole group, including lecturers, according to some participants.
Lecturer L1 finds it hard to see the student's emotions when meeting online, complicating the acquaintance process. L2 and L3 both thought that the online meetings were no barrier to getting acquainted with the students, even the contrary. In the developed design principles, some activities to promote the bonding between students were mentioned, such as organizing a virtual coffee shop, to compensate for the scarce physical meetings. However, the lecturers complained about a lack of time which prevented them to take action.

Facilitating interaction and discussion among fellow students and with the lecturer
Although the students seem reasonably satisfied with the social contact with their team members, they seem less satisfied with the amount and quality of the interaction with their fellow students as compared to physical education (Table 5.4A,C). One should realize, evaluating these figures, that physical education was brought back to a minimum due to COVID-19 restrictions. Dissatisfaction with the interaction with fellow students was not an issue in the focus group sessions. The participants evaluated Teams meetings as efficient and less distracting provided that everyone has their camera and microphone on. The participants liked the possibility of sharing their screens. For short messages and making appointments, they used WhatsApp. Tables 5.4B and 5.4C show satisfaction with interaction with their lecturers. According to the participants of the focus groups the communication with the lecturers, facilitated by Microsoft Teams, was faster and more continuous.

Table 5.4. Interaction data from the final measurement

		(A) Compared to the interaction experienced with fellow students in traditional (physical) education the amount of interaction increased	(B) Compared to the interaction experienced with lecturers in traditional (physical) education the amount of interaction increased	(C) Compared to the interaction experienced with fellow students in traditional (physical) education the quality of interaction improved	(D) Compared to the interaction experienced with lecturers in traditional (physical) education the quality of interaction improved
N	Valid	17	17	17	17
	Missing	0	0	0	0
Mean		2.53	3.12	2.94	3.06
Mode		3	4	3	3
Std. Deviation		.874	1.054	.827	.899

> "T*hey [the lecturers] are much faster and always available, say, at working hours and in college you have to walk to their working space. If he's there, then he's there, but if he's not there, then he's not there, so to speak, but then you have to come back again.*" (Tom)

During an online lecture, the threshold to ask questions seems to be higher, although one participant stated:

> *"But I do think: online there are also enough possibilities to have your say. you can raise your hand, you can just switch on your microphone, so the possibilities are there, but I think it also depends on the person whether to communicate online or only in a physical situation."* (Daniel).

The design of the minor contained four in-class discussion sessions. There were no assignments made for asynchronous online discussions. On their own, only five students agreed in the final measurement that they had asynchronous discussions using the chat functionality of the online learning environment and four preferred this possibility over an in-class discussion. Still, they all felt comfortable during the in-class discussions and 13 students agreed that they were helpful to understand the opinions of others and reflect on their own. Synchronous online discussions were appreciated in small groups but not in a setting with all students (26) present.

> "*On Teams, it is very easy to say nothing. For example, there was a group (…) that had prepared some nice propositions to discuss, but everyone always attends with their webcam and microphone off, and when they ask a question, few people think, oh, I'm going to switch on my microphone and I'm going to react. While if I'm in class and I ask Julia, what she is thinking, she has to react"* (Peter).

There are mixed feelings among lecturers about the interaction during online team meetings. During online sessions, L1 could not assess students' mental state by their body language and also thinks to be less convincing as a lecturer. The other two lecturers were quite satisfied with the online team meetings. They experienced not much difference with physical meetings regarding interaction, even, on the contrary, there were more communication opportunities. Nevertheless, L2 noted that online interaction seems to be an additional barrier for poorly communicating students. This additional barrier to asking questions also is apparent during online (guest) lectures. Although it always seems to be the same students who ask questions regardless of the way of communication, L2 and L3 remarked.
L2 was satisfied with the discussions during the online team meetings but stated not to have time to comment on the online chat discussions of students.

Activating knowledge transfer
Several learning activities supported this design principle. Every week a professional from the public sector delivered a guest lecture. Some took place online, others in a physical setting. Students presented an in-class workshop for their fellow students and conducted individual and collaborative research to gather knowledge about (a problem in) the public sector. The final measurement data indicated that most students were satisfied with the amount of theoretical knowledge they gained, in particular during their research activities (Table 5.5D). They were least satisfied with the workshops of their fellow students (Table 5.5E).

Table 5.5. Acquisition data from the final measurement survey

		(A) I gained much new theoretical knowledge about my profession during this minor	(B) I learned much during the online guest lectures	(C) I learned much during the in-class guest lectures	(D) I learned much by conducting research on my own (or with the group) on new concepts.	(E) I learned much during the workshops from my fellow students
N	Valid	17	17	17	17	17
	Missing	0	0	0	0	0
Mean		3.41	3.53	3.82	4.12	2.76
Mode		4	4	4	4	2
Std. Deviation		1.004	.624	.529	.697	.903

This dissatisfaction with the workshops from their fellow students is confirmed during the focus group sessions. One of the complaints was that the six (in-class) workshops were sequentially planned, making it difficult to keep concentrated, even though the assignment was to design an interactive workshop. The result, however, was that

> *"everyone had the same format, but only slightly different content, but the format was really very overlapping and then every time, you'd be in another workshop and then, you automatically grabbed your phone for one of those Kahoots or something, you know, because that was the same thing the whole time. That just makes it less interesting."* (Tom)

Hearing the experiences of public sector professionals during the guest lectures is activating in itself and this was appreciated by the students (Table 5.5B,C). The focus group participants added that the guest lectures supported their research activities. However, students and lecturers agree that an active working format during a lecture is also important. Guest lecturers do not always have the didactical skills to engage the students and have the additional disadvantage (especially during an online lecture), of not knowing the students. Interactivity is easier to achieve during an in-class lecture than online. This may be a reason why in-class lectures were more appreciated by the students (Table 5.5B,C).
L2 was less satisfied with the acquisition of knowledge by research, complaining about students not reading literature (given). As a consequence, the quality of discussions and assignments turned out to be, in some cases, inadequate.

Offering authentic, scaffolded and theory-based practice
Distinctive in this minor is the cooperation with professionals from the public sector motivating the students to acquire new concepts during the guest lectures as well as to put these concepts into practice by solving real-world problems. The students appreciated working on real-world issues and to create value for the stakeholders (Table 5.6B,C,D). This can be illustrated by a quotation from a participant of the focus group sessions who answered a question about assignments arousing curiosity:

> *"Yes, and I also think that you pay more attention to it [the assignment] because you want to deliver something really good because it actually is for a company or for someone else who is going to look at it, instead of just working on an assignment from school"* (Peter)

The minor's design intended to limit education-related travel, so students had the task to find an individual assignment in the public sector of their living area. This was less appreciated by the students (Table 5.6C). In the focus group sessions, organisational and content-related reasons were mentioned. Some students found it difficult to find an appropriate assignment

and some liked an assignment for a large organisation and not *"for the local football club"* (Tom). According to the lecturers, the student's main problems were inadequate communication skills and COVID-19 restrictions when acquiring assignments.

Table 5.6. Practice data from the final measurement survey

		(A) The minor assignments aroused my curiosity.	(B) In this minor, I developed solutions that can be applied in a real-world setting.	(C) During this minor, I created value for the public sector in my living area.	(D) It motivates me to carry out tasks aimed at creating social value.	(E) I got enough support from the lecturers to do the assignments properly.	(F) I missed visiting the organisations involved in our project.
N	Valid	17	17	17	17	17	17
	Missing	0	0	0	0	0	0
Mean		3.94	4.00	2.59	3.41	3.82	3.53
Mode		4	4	2	4	4	4
Std. Deviation		.659	.354	1.004	(D)	.636	1.007

Because of COVID-19, in most cases, the students couldn't visit the organisations, they worked for. They felt this provided an incomplete picture of the organisations involved (Table 5.6F).

> *"If you visit a website, for example, you might find out what the company stands for or the company's culture, but you'll probably get a completely different answer when you would walk around in that company and ask a few employees what they really think"* (Lucas).

According to the lecturers, most students became intrinsically motivated by carrying out assignments for external public organisations. By working in the public sector, one can add societal value. This aspect was the main reason for some students to choose this minor, while others became inspired during the minor by the authentic assignments and the guest lectures.

Collaborating for constructing a shared outcome through participation and negotiation with fellow students

Developing solutions for real-life problems also seem to be motivating when collaborating in a team (Table 5.7D). In this minor, a team consisted of four or five students. According to the final survey, students seem to be aware of the fact that it stimulated their learning (Table 5.7A) and responsible attitude (Table 5.7B). Most of them also agree on the fact that both online and physical interaction promoted the quality of their work (Table 5.7C). Still, there was not much opportunity for physical collaboration due to COVID-19 regulations. According to participants of the focus group sessions, this was not much of a problem:

> *"But I have the idea that now, I don't know maybe because we're older or something, but I have the idea that now [online] is more productive than when we were at school, because then people are, yes, you're sitting somewhere and then people are walking by and so you're watching. Phones are interesting"* (Tom).

The online meetings are experienced as productive, but participants emphasize the necessity to make clear agreements on deadlines and the distribution of work. After all, everyone has their own planning while studying at home.

At the end of the survey, the student could evaluate the minor as a whole. Almost all students evaluated the relationship between online and in-class learning as 'enhancing' or 'relevant to' each other.

Possible attitude change toward educational travel and online learning

This section examines a possible attitude change as a result of COVID-19 regarding students' motivation to attend on-campus learning activities and choice of travel mode by considering students' cognitive, affective and behavioural processes.

Table 5.7. Collaborating in a team. Data from the final measurement survey

		(A) I learned much from exchanging opinions and knowledge with fellow students during collaboration tasks	(B) I am content with my contribution to collaboration tasks.	(C) The quality of our collaboration tasks improved by collaborating both online and physically.	(D) Involving the work field motivated us to do our collaboration tasks
N	Valid	17	17	17	17
	Missing	0	0	0	0
Mean		3.82	4.18	3.82	4.18
Mode		4	4	4	4
Std. Deviation		.393	.393	.393	.529

At the start of the minor

The baseline measurement was meant to get a first indication of the attitude of the minor students towards education-related travel and online learning. They all experienced in the months preceding the start of the minor the restrictions imposed due to COVID-19. Travelling by public transport was not restricted but discouraged by the government, raising awareness of potential health risks. One of the measures was also a transition to remote emergency teaching where students gained experience with online learning methods.

To measure their knowledge of online learning activities, students were asked to mark a list of online learning activities with which they have had experience in the past. This list contained: online lecture, online practice, online question hour with a teacher (group-wise), online

discussion with fellow students, online instruction video, an online individual coaching session with a teacher, online meeting with a project group, collaboration through an online platform, use of social media for study purposes, formative online knowledge test, summative online knowledge test and gamification for study purposes. Most online activities were familiar to the students, except for the use of social media (familiar for 9 students), formative knowledge test (8 students) and gamification (2 students). Table 5.8 shows how they experienced online learning compared to on-campus learning. The results are slightly in favour of on-campus learning, especially during collaboration activities. Still, students seem to acknowledge the online learning possibilities when looking at their preference for a mix of an on-campus and online learning model. Students showed appreciation for their online communication with lecturers and fellow students (affective process) but also missed having face-to-face contact (Table 5.9). When asked about their negative experiences with online learning most statements are about impaired social contact and personal attention, loneliness, and easy distraction. Almost everyone mentions 'no travel time' as a positive experience and also (not as frequently) efficiency, flexibility and easy communication possibilities. To get an indication how the students' travel experiences during the COVID-19 pandemic affected their attitude towards a particular travel mode, they were asked to rank their reasons for choosing a travel mode before and during the COVID-19 pandemic. Before COVID-19 the rank order is 1. time, 2. money, 3. convenience, 4. flexibility, 5. reliability, 6. safety, 7. health, 8. environment. During COVID-19 it is 1. time, 2. money, 3. convenience, 4. flexibility, 5. reliability, 6. health, 7. safety, 8. environment. The only difference is that 'health' changed positions with 'safety' during COVID-19. Still, this may be a temporary change because of the infection risks of COVID-19. The same picture arises from their open answers about positive and negative experiences with their travel mode. Travel time, costs and convenience are mentioned most frequently. "Wearing face masks" (2), delays (12) and crowded trains or busses (7) are mentioned as inconveniences of public transport. When asked about how satisfied students were with their chosen travel mode (affective process), 77.5% of the students were satisfied with their chosen travel mode. Still, only 11% would choose the same travel mode after graduation.

At the end of the minor

In the final measurement survey, the students were asked about the most and least efficient aspects of this blended minor. Just as at the beginning of the minor, most students mention "less travel time" as one of the most efficient aspects. Also, "online meetings" are mentioned and this differs from the earlier survey. As least efficient, they mention, among other things, the (online) guest lectures, interaction possibilities, and online discussions.

During the two focus group meetings and in the survey, the students were also asked about their travel experiences. At the beginning of the minor, one student intended to commute by car to the campus but in reality, five students did. Table 5.10 depicts to what extent COVID-19 or the blended learning model caused this behaviour. In the focus group meetings, on the question of how COVID-19 affected the travel mode choice, a student stated:

"Since Corona started, I haven't really travelled by public transport anymore and nowadays I commute to college by car. Also, because I only need to travel once or twice a week (...) if it was five times a week, I would travel by public transport. Otherwise, it would be too expensive". (Lucas)

Table 5.8. Opinions of the students about on campus and online learning activities (baseline measurement survey).

		I learn more during an on-campus lecture than when I watch a recorded video at home.	I learn more when I work on my assignments during an on-campus tutorial than completing them at home.	I learn more when I collaborate with my fellow students on-campus than in an online learning environment.	I think a mix of on-campus and online education is the best educational model.	Online learning did not have a negative influence on my learning outcome
N	Valid	26	26	26	26	26
	Missing	0	0	0	0	0
Mean		3.54	3.42	3.62	3.81	3.15
Mode		3	3	3	4	4
Std. Deviation		1.067	1.065	.898	.849	1.047

Table 5.9. Satisfaction with online learning (baseline measurement survey).

		I appreciated the communication online with my fellow students.	I appreciated the communication online with my teachers.	I missed the face-to-face contact with my fellow students.	I missed the face- to-face contact with my teachers.
N	Valid	26	26	26	26
	Missing	0	0	0	0
Mean		3.23	3.69	3.85	3.58
Mode		4	4	4	4
Std. Deviation		1.070	.618	.925	.809

Other reasons given are: avoiding crowdedness in public transport, less travel time, more easy to borrow a car (from parents) if you need to commute occasionally. Still, the majority stated that COVID-19 made no difference regarding their travel mode choice and, in most cases, remained public transport. In the Netherlands, all students of 18 years or older receive a free public transport card and so, low travel costs were mentioned as a reason.

a. Multiple modes exist. The smallest value is shown

Table 5.10. Final measurement data about preference for commuting with a car.

		Because of COVID-19, I prefer to go to college by car rather than by public transport	I prefer to go to college by car because I only have to travel to college once every few weeks
N	Valid	17	17
	Missing	0	0
Mean		3.18	3.35
Mode		2[a]	2[a]
Std. Deviation		1.286	1.367

Triggered by the COVID-19 restrictions, cognitive, behavioural and affective processes causing a potential attitude change of students towards educational travel and online learning have been studied at the start and end of the minor. Students experienced the pros and cons of online and blended learning and this may change their motivation to attend classes if an online alternative is available. All students appreciated the time savings due to less travel time and a number of them also the productive and efficient online meetings. The preference for online collaboration changed throughout the minor program, with a shift from on-campus collaboration being favoured initially (as shown in Table 5.8) to a preference for a blended collaboration by the end of the program (as shown in Tables 5.7A and 5.7C), also confirmed in the focus group sessions. This shift indicates an attitude change toward online collaboration and may have an effect on their decision whether to travel to the campus for collaboration purposes.

5.4 Discussion and Conclusion

This study's main objective was to develop and evaluate pedagogical design principles for a sustainable blended learning configuration. This only partly succeeded because the evaluation of this configuration and student travel behaviour was affected by COVID-19 restrictions. Therefore, we adapted our research design by incorporating the impact of these restrictions in our evaluation. In this section, we discuss the findings based on the three research questions and address research limitations, ending with some concluding remarks.

Experiences of the design team (RQ1)

A multidisciplinary team designed the blended minor with the assistance of academic expertise. The developing team had their reservations about the constructive alignment approach. To understand the reason why one needs to know that the team members had no prior experience in designing blended learning and integrating technology. These two factors are mentioned as prerequisites for an effective blended learning design (Alammary, Sheard, & Carbone, 2014). In such circumstances (inexperienced blended learning designers) a more iterative approach would probably be more effective.

A logistical issue concerns the lecturer's workload model based on traditional face-to-face education. Some blended learning interventions ask for more time commitment than acknowledged in these workload models, for instance, participation in discussion fora, regular personal approaches, and online responses to questions. This problem corresponds with previous research showing that the online experience increases the workload of lecturers due to inappropriate allocation of time (Mendieta Aguilar, 2012; Phillips & Phillips, 2016; Ustun & Tracey, 2020; Wanner & Palmer, 2015).

The implementation of the sustainable blended learning design (RQ2)

The implementation of the blended minor is evaluated by studying the experiences of the students and lecturers. Six design principles were developed to serve as a basis for sustainable blended learning (Appendix C). All design principles proved to be relevant but their application also revealed some issues. Although the blend differed from the original planning in favour of online learning due to COVID-19 restrictions, the minor students stated that they had no trouble managing their own time and appreciated studying anywhere and anytime. Previous research confirms this appreciation but shows less belief in the former statement, that is, the self-regulation skills of the students (Hall & Villareal, 2015; Powers, K. L. et al., 2016). Also, the lecturers have reservations about their students' self-regulation skills. They expected a deep learning approach (orientation toward understanding), but sometimes experienced a surface learning approach (orientation toward reproduction) of the students. This may have nothing to do with the blended context because, according to Ellis and Goodyear (2013), students' approaches to learning tend not to differ across on-campus and online contexts. The students

with a surface learning approach might have benefited from more direct feedback on their performance (online tests, quizzes) which are stimulating (Tsai, 2014).
Collaborating in a team, while constructing knowledge in an online learning environment, created a sense of community for the students, as confirmed by Vaughan (2010). Still, this was limited to their team. To create a community feeling among all minor students more actions are needed, for instance, regular online icebreakers (Keengwe, 2014, p. 90) or a virtual café (Keengwe, 2014, p. 114), but lecturers experienced a lack of time to organise this due to a failing workload model. This was also a lecturer's reason for not promoting or facilitating asynchronous online discussions. These discussions provide the student with the opportunity to reflect on what has been said (or read) to make thoughtful contributions (Laurillard, 2013, p. 148). It could have been useful for stimulating students to read the literature provided, especially students with a surface learning approach, to discuss the findings, asynchronously as well as synchronously, using an online discussion board and meeting application. Pratama et al.(2020) studied the use of online meeting applications and concluded that "the video conference is proven to be more efficient, practical, and safe" (Pratama, Mohamed Nor, Kassymova, & Duisenbayeva, 2020, p. 65), corresponding with the minor student experiences. Although Keengwe (2014) claims that peer instruction promotes students' self-confidence and provides opportunities for reflection, the (in-class) workshops of fellow students were mostly not appreciated by the minor students. It shows that not only the content is important but also the way it is organised. That also applies to the (online and in-class) guest lectures from professionals in the public sector. These were highly relevant and therefore motivating (Laurillard, 2013) but sometimes not activating by the lack of didactical skills of professionals. The minor students appreciated working on real-world issues and creating value for the stakeholders and, according to the lecturers, became intrinsically motivated. Previous research confirms that if an assignment is perceived as relevant by students, they become more motivated (Keller, 2008). Motivating was also the collaboration with other students working on the assignments. This is confirmed by other research (Baranova et al., 2019; le Roux & Nagel, 2018; Vaughan, 2010).

Indicators for an attitude change toward educational travel and online learning (RQ3)
The findings show some indicators that the COVID-19 restrictions could have been a trigger for an attitude change in students toward commuting. Experiencing advantages of online learning such as time savings due to less travel and efficient, productive online meetings influenced their attitude toward online collaboration. This attitude change becomes even clearer when compared to the findings of the pre-COVID-19 study on student travel behaviour which showed a clear preference for on-campus collaboration (Versteijlen et al., 2021). This is in accordance with Van Wee and Witlox (2021) who state that fewer constraints regarding time and space might change the balance between the pros and cons of making a trip and online working. However, it should be noted that during our study, students were still experiencing primarily online education and further research is needed to determine if this attitude change

toward online collaboration is not temporary and influences the decision to make a trip to campus.

The reasons to choose a particular travel mode did not change much, as compared with the pre-COVID-19 student travel behaviour study (Versteijlen et al., 2021). In both studies, the students mentioned costs, time and convenience as the primary incentives. Still, in the blended learning context, an additional reason to choose a car appeared, that is, it is easier and less expensive to borrow a car (from parents) commuting occasionally. This behaviour may be temporary and does not necessarily lead to an attitude change toward a travel mode choice.

Research limitations and future research

In this study, the pedagogic design principles are underpinned by previous research and their potential in a real-life context is explored. In design-based research, the developed principles should be evaluated and refined across different real-life contexts. These contexts can differ in organisational policy, lecturers, student groups, learning subjects and so on. So, the main limitation of this study is that it is based on a single case study. The purpose of this exploratory study was to create an empirical basis for generalisation and knowledge construction in future research, in which the developed design principles can be refined across a variety of educational situations. When evaluating these design principles in a different context, it is recommended to adapt the lecturer's workload model to one that is more appropriate for blended learning (Dekeyser, Watson, & Baré, 2014).

We chose to evaluate the blended learning study programme with student surveys, student focus groups and interviews with designers and lecturers. In this way, we were able to gain an in-depth understanding of their motivations and considerations. Nevertheless, another approach using learning analytics or observational methods would probably provide additional data and could be used to verify the opinions of the participants. In this study, a student's opinions were verified by the observations of the lecturers and fellow students.

A completely different approach might have been a context-dependent Stated Choice experiment, which asks from participants to make choices between alternatives assuming that a certain context applies (Molin, 2014). Applying this approach, students can indicate their preferences/intentions in a blended learning and a traditional learning context. An advantage of this approach is that researchers can offer more alternatives to the students. Nevertheless, it remains unclear whether students will actually make the choice they say they will. In our research, we evaluated the actual choices of both students and lecturers. Another reason for choosing EDR is its strong connection to educational practice and therefore contributing to greater practical relevance through the development of six pedagogical design principles.

As a possible environmental impact of this blended design, we focused on student travel behaviour because student travel probably has the largest impact on the carbon footprint of a HEI. Nevertheless, there are more possible effects, such as the effect on the energy consumption

of campus site operations or on student housing. Further research is recommended.

Concluding remarks

During one of the focus group meetings, one of the minor students stated that "blended learning is the way to go!" The minor students appreciated the freedom to make their own choices about where and when to study. Still, to ensure that this freedom does not interfere with the quality of their learning a new balance between virtual or physical spaces, learning activities and moments in time should be created. We developed not only pedagogic design principles to support creating this balance, but we also demonstrated that experiencing online learning probably has changed the willingness of students to attend on-campus learning activities. The proposed blended learning configuration meets the student's needs to make their own choices concerning spaces, time, relations, resources and activities. In addition, its flexibility provides opportunities to organise education efficiently and sustainably.

Appendix A

Baseline measurement table

Category	Variables	Measurement Details
Demographic	Age	Number (19 25, 26 40)
	Living conditions	In digs, with parents, in the neighbourhood or within travel distance of Avans UAS
	Travel distance in kilometres (now and before)	This period, before this period 0-5, 6 10, 11 20, 21 50, 51 100, more, namely.
	Travel time in minutes (now and before)	Number
	Frequency of travelling to college (average number of times per week)	Educational period before Corona: on average
	Usage of car	In possession, borrowing, sharing, no usage
	Travel mode (now and before), in most cases	This period, before this period Public transit (train, metro, bus), car (driver), bicycle, e bike, motor, walking, carpool (passenger), other
Cognitive	Knowledge about online learning, activities	Online activity: lecture, practice, discussion, coaching, acquisition, meeting, social media, formative/summative tests, gamification, other
	Social influences (reason to attend class, reason to choose travel mode)	5 point Likert scale (Strongly Disagree, Disagree, Undecided, Agree, Strongly Agree)
Affective	Satisfaction with travel mode	5 point Likert scale
	Satisfaction with online/on campus learning	5 point Likert scale
Behavioural	Experiences with a travel mode (before/after COVID 19 crisis)	Classify reasons for choosing: Time, money, convenience, environment, health, flexibility, safety, reliability
	Attendance	5 point Likert scale
	Experiences with travel, learning environment	Open questions: Negative (3)/positive (3) experiences

Appendix B

Final measurement table

Category	Variables	Measurement Details
Demographic	Place of residence	Open question
	Date of birth	Date
	Gender	Male/female
	Former college	Open Question
Student commute	Travel mode	Public transit (train, metro, bus), car (driver), bicycle, e bike, motor, walking, carpool (passenger), other
	Travel choice	5 point Likert scale (Strongly Disagree, Disagree, Undecided, Agree, Strongly Agree)
	Travel to non study activities	5 point Likert scale
Learning process	Flexibility	5 point Likert scale
	Self-regulation	5 point Likert scale
	Formative feedback	5 point Likert scale
Community feeling	With lecturers	5 point Likert scale
	With fellow students	5 point Likert scale
Interaction and discussion	With lecturers and fellow students	5 point Likert scale
	Quality of interaction	5 point Likert scale
	Online vs. on campus	5 point Likert scale
	Reflection	5 point Likert scale
	Discussion (online in class)	5 point Likert scale
Acquisition	Quality	5 point Likert scale
	Questions to lecturers	5 point Likert scale
Practice	Authentic assignments	5 point Likert scale
	Social value	5 point Likert scale
	Supervision	5 point Likert scale
Cooperation	Quality	5 point Likert scale

	Professional field	5 point Likert scale
General	Alignment online in class education	Reinforce each other, are aligned, little aligned, not aligned
	Effectivity blended education	Open question (most, least)
	Suggestions for improvement	Open question

Appendix C

Table C.1. Design principles structured according to CIMO logic (Denyer et al., 2008, pp. 393 413)413). Numbers between brackets refer to the literature included (Table C.2).

Design principle	**Context**	**Intervention**		**Mechanism**	**(Possible) Outcome**
		In-class	**Online**		
Aiming at self regulation in a student's learning process	In blended learning self regulation is a key concept for success[1] Different types of feedback: Intrinsic feedback, extrinsic feedback [11], peer feedback. Feedforward, feedthrough: [10].	Introduction session about goals, tasks, organisation and technology [1][8][7,p7] Coaching of students [1][18] Intake interviews [18] Adjustment: extrinsic feedback [1] Evaluate: summative test [1]	Orientation: online test about prior knowledge [1] Monitoring: formative tests, peer feedback, reminders, reports, activity in discussion fora [1] Adjustment: intrinsic feedback [1] Evalua te: summative test [1]	Motivation to learn is promoted by [14]: - knowing what can be expected (learning goals, tasks) - feedback that enables to adjust (self regulatory) learning strategies if necessary	Improved self regulatory skills Peer assessment: promotes performance and motivation [3]
Fostering a sense of community	Students feel more engaged if they have a sense of belonging to a group.[11] This is important because online learning can create a sense of isolation [1][11].	Introduction session [1]	Gather and show info about students: description, photos, personal background film[1][6] Lecturer: (carefully planned) online icebreakers [13,p. Regular, personal approach of lecturer [6,p.105][Virtual coffee shop [13,p114]	Online ice breakers create student engagement, interaction and a supportive positive learning environment [13, Students feel safe, accepted and valued[1]	Motivated students[1] High degree of social presence[8]

Design principle	Context	Intervention		Mechanism	(Possible) Outcome
Facilitating interaction and discussion among fellow students and with the lecturer	The internet ensures more interaction opportunities for HE students. Online interaction is place and time independent and can reach many people at once.[4] Students do not want to lose social interaction and the 'human touch' of the in-class environment.[1] Interaction with lecturer is necessary for extrinsic feedback and asking questions [15]	Discussion about a subject under supervision of a lecturer [16,p.145] Online discussions are discussed and commented on by the lecturer [2]	Communication platform with chat functionality to share information and asking questions [1] Discussion board with functionality to [16,p. 54]: • indicate the type of contribution (e.g. claim, comment) • take a different role (e.g. moderator, starter) Use of social media [1] Lecturer creates guidelines for online discussion and ensures they are followed [8] [7,p79] [16,p.156]. An online 'Frequently Asked Questions' discussion forum [7,p102] Gamified online discussions [5]	Online interaction: feelings of safety, anonymity, and connection challenge students to take different and sometimes controversial positions[17] [16, p.148]. Asynchronous online discussion provides the student with the opportunity to reflect on what has been said in order to make thoughtful contributions [16, p.148]. Discussion (guided by a lecturer [16, p.151]) helps students to develop their critical thinking skills [16,p.145] Student develops conceptual understanding by asking questions to the lecturer and by adjusting actions after processing feedback[15]	Online interaction: increase of learning productivity, a deeper approach to learning, development of communicatio n skills, improved understanding of content[17].

Design principle	Context	Intervention		Mechanism	(Possible) Outcome
Activating knowledge transfer	Blended learning allows for more personalised instruction [2]. The challenge is to make the transfer of existing theory about a subject an active process [16,p.110] Students can conduct their own research to acquire knowledge in a way that is structured by the lecturer. [16, p105]	Peer instruction (presentation) [13, p.89] Discussion of online student contribution. Eliminating misunderstandings [2] Discussion of online learning (key concepts) [7,p.100] The use of a Group Response System [16,p.118] [4,p.100] (e.g. Kahoot, Socrative)	Peer instruction (portfolios, writing assignments) [13,p.89] Students are presented with learning material in different forms (e.g. knowledge clips (with self-test), podcast) [1][14] Web lecture Students analyse contrasting cases by identifying patterns and working these into a diagram (preparation for lecture)[16, p.121]. Interactive tutorials [12]	Peer instruction promotes student self-confidence and provides opportunities for reflection[13,p.89]. Curiosity on the part of students due to variation in the form of the material presented [14]. By clarifying the internal structure of texts/concepts by the lecturer, the student develops analytical skills [16, p.112]. Inquiry-based learning encourages an active attitude and independence on the part of the student [7, p.126]	Students can learn at their own pace by choosing the methods of knowledge transfer best suited to them[1] [16, p.110]
Offering authentic, scaffolded and theory- based practice	Assignments are perceived as motivating if they are in line with the student's learning goals[14] [16,p.73]. Complex tasks for the student are offered scaffolded (Hammond & Gibbons, 2005) in such a way that they fall within the student's capabilities [16,p.77] ("zone of proximal development").	Coaching by a lecturer (teaching presence) [8]. Initiation of assignment[7, p.100] Provide students with the recognition they deserve after completing the assignment [14].	Tasks with intrinsic feedback [15] Variation through (serious) games, quizzes and puzzles [1] [16,p.180] Personalised assignments based on student's prior knowledge [1][14] Coaching by teacher(teaching presence) [8] [13,p,84]	A student is more motivated if the assignment is perceived as relevant [14]. Through scaffolded guidance from the lecturer, the student develops the self- confidence to acquire new skills and understanding [9].	By producing output in response to the practical assignment, the students have the opportunity to demonstrate their conceptual understanding [16,p105]. Students understand the assigned practical tasks and can perform them well [9].

Design principle	Context	Intervention		Mechanism	(Possible) Outcome
Collaborating for constructing a shared outcome through participation and negotiation with fellow students	Small group assignments promote opportunities for sharing ideas and experiences and developing camaraderie[7, p83]. When expectations and guidelines are clear, a team project can engage the student in relevant and realistic problem solving [7,p85] Social value of the peer group as the vehicle for motivation and enabling processes of negotiation, learning and shared output [16, p.185]	Coaching by teacher (teaching presence)[8]. Teacher monitors learning process and outcome of the group process[16, p.187] Brainstorming [7, p79] Discussion about 'self-directed' learning. A survey can be used[13, p.152]. Initiation of group project[7, p.100]	Coaching by teacher(teaching presence) [8] Students share ideas and information [7,p.83]. Teacher encourages self-responsibility and self- management [7,p86]. The postings of students give the opportunity for reflection and insight [7,p.89][16, p.189]. Having students complete a survey (see f2f session)[13, p.152]. The use of a wiki [16,p.192]	Students know what they need to do (self-appraisal) and can also carry it out successfully (self- management) [7, p.33]. Interaction with fellow students gives a student the opportunity to learn from and build on the results of their fellow students through: "elaboration, explanation, argumentation, and question asking "[15].	Students go beyond just exchanging information. They can also integrate and apply the theoretical concepts [8].

Table C.2. References to numbers in the table

No	Reference
1	(Boelens et al., 2017)
2	(Boelens et al., 2018)
3	(Bouwer et al., 2018)
4	(Castaño-Muñoz et al., 2014)
5	(Ding et al., 2017)
6	(Filius et al., 2018)
7	(Garrison and Vaughan, 2008)
8	(Garrison and Arbaugh, 2007)
9	(Hammond and Gibbons, 2005)
10	(Hummel, 2006)
11	(Jeffrey et al., 2014)
12	(Jensen et al., 2018)
13	(Keengwe, 2014)
14	(Keller, 2008)
15	(Laurillard, 2009)
16	(Laurillard, 2013)
17	(Owston et al., 2013)
18	(Vanslambrouck et al., 2018)

CHAPTER 6 General conclusions and discussion

6.1 Introduction

The central question in this PhD thesis is: How can sustainability-oriented blended learning in higher education be designed to reduce carbon emissions due to student travel behaviour without compromising educational quality? The objective was to explore this subject from the perspectives of the stakeholders and to incorporate their views into a design that would be implemented and evaluated as a first prototype of sustainable blended learning. This objective was partly overturned by the COVID-19 pandemic. Chapters 2 and 3 examine stakeholder thoughts and opinions prior to COVID-19, while the resulting design and implementation, discussed in Chapter 5, took place and was evaluated during the pandemic, in which government restrictions limited on-campus education and discouraged travel. The sustainable blended learning design could therefore not be implemented as planned. Nevertheless, the implementation of the design principles could be evaluated because a limited amount of on-campus education was possible. However, measurements of the carbon emissions as a result of this blended prototype would be meaningless. Instead, the blended learning prototype is evaluated on attitude changes of students after experiencing online learning extensively during the COVID-19 period and whether these experiences will affect a student's willingness to commute to campus when an online alternative is available.

This chapter starts with presenting the main findings of the four studies while answering the underlying research questions. The scientific relevance of these results is presented in the next section followed by reflections on the used methodology and limitations of this study with suggestions for further research. This chapter ends with implications for educational policy.

6.2 Overview of results

In Chapter 2, the potential of online learning as a measure to reduce HEIs' carbon footprint by a reduction of commute-related travel is explored with the research question: what impact could the adoption of online learning in (Dutch) higher education have on reducing its carbon footprint through a reduction of student and staff commuting, and on educational quality? To answer this question, the first step was to get a notion of the magnitude of emissions caused by commute-related travel in HE and its proportion of the HEI's carbon footprint. Dutch reports using the Greenhouse Gas Protocol (WBCSD, 2014) to calculate the carbon footprint of a HEI revealed that the emissions due to staff and student travel range from 40 to 91 per cent of the carbon footprint. The absolute emissions of commuting range from 340-630 kg CO_2e per student per year and 410-540 kg CO_2e per employee per year. These figures are only rough estimates because the data collection on student travel was not carried out with the same level of accuracy. Nevertheless, they correspond with data from studies from other countries about the HEI's carbon footprint. Even though student commuting contributes significantly more to the carbon footprint compared to staff commuting, the efforts to decrease these carbon emissions are mainly focused on staff commuting without much success. according to the interviewed energy/ICT/sustainability professionals of Dutch HEIs. They also state that online learning to reduce commute-related emissions is hardly considered due to the notion of policymakers that regular face-to-face contact promotes the quality of learning. The interviewed online or blended learning experts (lecturers and policymakers) showed a more nuanced view of the use of online learning in HE. They were concerned about deteriorating social processes but appreciated the opportunities for personalisation and multi-media acquisition of content. The possibility of online learning providing an opportunity to reduce the carbon footprint of a HEI was unknown to these experts.

After exploring the thoughts and opinions of the educational staff of HE, the measure of using online learning to reduce students´ commuting to and from campus was studied from the perspective of Dutch students in Chapter 3 in an attempt to answer the question: What are the considerations and (de)motivators of students influencing their travel mode choices and their decisions whether to travel to their institution or to study (online) from home or a place that does not require travelling? To gain in-depth insight into the thoughts and considerations of students, five focus groups were organised containing social, economic and technical bachelor students from different study phases. Almost all participating students needed to travel to the institution by car or public transport to attend classes. The effectiveness of travel regulating measures, such as a free travel permit and high parking costs, to change travel mode choices towards a low-carbon one was confirmed by this study. Most students commuted by public transport and low or no travel costs were mentioned as the most important consideration followed by travel time, reliability and convenience. Environmental considerations and safety issues were hardly mentioned. Although travel costs were not an issue, travel time was when

deciding whether to make the trip to campus or to stay at home studying online. This travel time was weighed against the number of scheduled classes and the time of day they were taught as well as the type of learning activity and their perceived learning abilities, such as the ability to concentrate, perceived complexity of theoretical concepts, and the need for feedback and answers on questions. This recurring decision seems to be a reasoned choice and stems from their attitude towards on-campus as well as towards online learning and behavioural control, following the Theory of Planned Behaviour. Students viewed online learning as a suitable substitute for on-campus learning in situations that involve low-interactive activities such as lectures or library studying. However, they thought it was important to be physically present on campus for activities that require more interaction, such as collaboration or practice activities. Most students showed a positive attitude towards clustering learning on campus one or two days per week. According to the participating students, this probably will not lead to increased travelling to non-study activities on 'online learning' days. This also depends on their opportunities and social contacts in their immediate residential area.

The next step is to address how to incorporate the explored needs, concerns and expectations of the key education stakeholders into a high-quality design of blended learning. In Chapter 4, a literature review is described following a realist research approach answering the question: Which pedagogical design principles and recommendations can be extracted from scientific theory and empirical studies about blended and sustainability-oriented learning? The first three developed design principles meet the concerns of the interviewed educational practitioners, described in Chapter 2. These are about aiming at self-regulation during a student's learning process, fostering a safe and social learning environment and facilitating (a)synchronous interaction and discussion. The other three design principles provide directions for learning activities, that is, activating knowledge acquisition, working on authentic tasks and collaborating in a technologically-enhanced learning environment. A complete list including recommendations can be found in Table 4.6. Some missing elements were observed after analysing the design principles for their suitability for sustainability-oriented education. In the learning process, it is important to aim at self-awareness of a student's own values regarding sustainability issues. During inquiry activities, new knowledge should be constructed for contributing to sustainability and while bringing this new knowledge into practice the corresponding tasks should not only be authentic but also action-oriented. And last, collaboration activities should make use of the technologically-enhanced learning environment to promote "diversity across cultures, social groups, communities, and individuals" (Wiek et al., 2011, p. 211).

The literature review, described in Chapter 4, started in support of a team of eight educational professionals who were in the process of designing a sustainable blended study programme, a so-called minor. This team developed the minor in cooperation with the PhD researcher, described in Chapter 5 and this process of design and implementation answered the last research sub-question: How can a sustainable blended learning study programme be designed and implemented in higher education? In designing the minor, the concepts of constructive

alignment were applied, beginning with making explicit the learning objectives and associated assessments. This tiered approach is probably less suitable for designers with little blended learning experience because a blended design affects not only the learning activities but also its assessment. The lecturer's workload model was an issue during the design as well as the implementation stage. This workload model is based on traditional in-class education and does not take into account the time needed to coach students during their online learning period. Developed by the researcher in consultation with the design team, the pedagogical design principles evolved during the design process (Chapter 5, Appendix C, Table 1).

This first prototype of the design-based research started with 26 fourth-year students and three lecturers. This implementation took place during the COVID-19 pandemic and government restrictions diminished the in-class education to half a day per two weeks. Therefore, the impact of these restrictions on students' attitudes towards online learning and commuting in comparison with the study described in Chapter 3, was also evaluated.

The evaluation of teaching and learning is based on how lecturers and students perceived the implementation of the pedagogic design principles. Regarding Aiming at self-regulation in a student's learning process, there was some discrepancy between how students thought about their self-regulation skills and how lecturers perceived them. The students stated that they had no trouble managing their own time and appreciated studying anywhere and anytime. Still, the lecturers showed reservations, especially about students reading the assigned literature. A sense of community was fostered by the online meetings with their team of four students but this did not apply to the mostly online lectures attended by the whole group. Compared to traditional education the student experienced the amount and quality of interactions with fellow students as insufficient and with lecturers as sufficient. The lecturers did not stimulate asynchronous online discussions as a follow-up of in-class discussions due to a failing workload model, allocating a limited amount of hours for lecturers to teach scheduled sessions. Activating knowledge transfer through guest lectures and research was appreciated by the students but were less satisfied with the workshops from fellow students. Practice assignments were mostly conducted in collaboration with other students. The students became intrinsically motivated by working on real-world issues and creating value for the stakeholders. Working in a team stimulated students' learning and the online meetings were experienced as productive.

The COVID-19 restrictions may have been a trigger for an attitude change of students toward educational travel. Experiencing the advantages of online learning (e.g. time savings due to less travel and productive online meetings) may influence their motivation to attend classes if an online alternative is available. Also, an additional reason to choose a car appeared, namely, it is easier and less expensive to borrow a car (from parents) commuting occasionally.

6.3 Relevance for science

In this PhD research, the educational and environmental impacts of learning in higher education were balanced in the process of finding guidelines for designing a sustainable study programme. It weighed the environmental impact of student commuting against the impact of providing on-campus education on fewer days a week on the quality of education. This integrated approach, combining theoretical concepts of two disciplines, transport and education, is innovative and, as far as we know, has never been applied before. The integrated approach resulted in a deeper understanding of student travel behaviour in relation to learning and six pedagogical design principles for sustainability-oriented blended learning with associated recommendations to guarantee the quality of education.

A blended learning design has the potential to reduce student commute and enhance educational quality. It has extensively been researched for its opportunities regarding flexibility (Bozkurt & Sharma, 2021; Müller & Mildenberger, 2021), quality (López-Pérez et al., 2011; Owston et al., 2013), personalisation (Alamri et al., 2021; Boelens et al., 2018), collaboration (Garrison & Vaughan, 2008) and so on, but never for its opportunities to reduce student travel and support the development of sustainability competencies.

Existing research establishes the impact of commute-related travel of students on the carbon of a HEI (Caird et al., 2015; Klein-Banai & Theis, 2013; Valls-Val & Bovea, 2021), but in transport studies, solutions are sought within the same discipline, that is, stimulating students to commute by a low-carbon travel mode such as public transport or bicycle instead of by car (Hancock & Nuttman, 2014; Whalen et al., 2013; Zhou, Jiangping, 2014). The solution to limit the travel movements of students by an educational design using online learning is sometimes mentioned (Zhou, Jiangping, 2014) but hardly studied. And occasionally, in educational studies, decreasing student travel commute is mentioned as a possible positive spin-off of a blended design (Caird & Roy, 2019).

To conceptualize student travel in relation to on-campus and online education three conceptual models of travel behaviour were used: the Conceptual model of Travel Behaviour (Van Acker et al., 2010), the NOA model (van Wee et al., 2013, chap. 3) and the Theory of Planned Behaviour (Ajzen, 1991), resulting in the model Travel for Learning (Chapter 3). The first model by Van Acker et al. (2010) is based on the hierarchical decision structure (Salomon & Ben-Akiva, 1983) and distinguishes three levels of individual decisions, that is, long-term (e.g. on lifestyle), medium-term (e.g. location in relation to study/work) and short-term (e.g. daily activities and travel). These decisions are made in conjunction with each other. The hierarchical decision structure placed the student's short-term decision to travel to campus in a broader perspective. While acknowledging the influence of long-term and medium-term decisions of students, this PhD research is focused on their short-term behavioural decision regarding commuting to campus. The last two theoretical models (Ajzen, 1991; van Wee et al., 2013) take a psychological perspective and model the motivational factors that

affect the behavioural choice of an individual. The derived initial model Travel for Learning depicts the factors motivating students to attend on-campus learning, non-study activities or choose a travel mode. The associated empirical study (Chapter 3) delivers the extent to which these motivational factors affected the reasoned choice of students to attend and the more habitual choice for a travel mode. When deciding to attend on-campus education, the students evaluated their learning on campus taking into account the effort required for travel, and contemplating the possibility of an available online alternative. This decision process corresponds with the concept of making a reasoned choice dependent on motivational factors, as in the NOA model (van Wee et al., 2013, chap. 3) and the Theory of Planned behaviour (Ajzen, 1991).

The Travel Behaviour Study findings were considered while developing the design principles for blended learning. The design principles are rooted in three theoretical frameworks: the Conversational Framework of Laurillard (2013), the Community of Inquiry Framework of Garrison and Vaughan (2008), and, as we framed it, the Integrative Relational Framework of Ellis and Goodyear (2010), which collectively encompass different perspectives on learning. These include the interactions between students and lecturers and among students integrating theory and practice (Laurillard, 2013), the social, cognitive and teaching aspects of collaborative learning (Garrison & Vaughan, 2008), and the need to balance online and on-campus learning from an ecological perspective (Ellis & Goodyear, 2010). Boelens (2017) identifies four key challenges to designing blended learning, that is, incorporating flexibility, facilitating interaction, facilitating students' learning processes and fostering an affective learning climate. The author sees this as a first step in establishing a detailed blended learning framework which is lacking in the literature (Boelens et al., 2017). The design principles developed in this PhD study can be considered as a second step.

Moreover, the design principles were developed from a pedagogical as well as a sustainability perspective. Blended learning applying the pedagogical design principles produces high-quality education but the question remains whether this design is conducive to sustainability-oriented education. For answering this question, the principles were contrasted with what is needed to develop sustainability competencies. Regarding these competencies, the key sustainability competencies as defined by Brundiers et al. (2021), based on the work of Wiek et al. (2011), are used, supplemented with theoretical research about the pedagogical approach how to develop the competencies (Lambrechts et al., 2013; Lozano et al., 2017; Tejedor et al., 2019; Wals, 2019) and empirical studies implementing this pedagogical approach. This results in pedagogical design principles for sustainability-oriented blended learning which can be considered a contribution to both educational science and educational practice.

6.4 Reflections on methodology

This PhD study aimed to find whether the application of a blended learning design can lower the carbon footprint of a HEI by decreasing commute-related travel of students without compromising educational quality. This objective had to meet several challenges. First of all, there is not much reliable data about student travel emissions as part of the carbon footprint (Klein-Banai & Theis, 2013; Valls-Val & Bovea, 2021). Secondly, the few student travel behaviour studies focus their research on changing the travel mode of students to a less carbon-intensive mode and not on decreasing the students' travel movements. So, not much is known about the considerations and motivations of students for making the trip to campus. Thirdly, there is no prescription for how to design high-quality blended learning. Moreover, the design options are almost unlimited (Moskal et al., 2013) and need to be adapted to different circumstances (Graham et al., 2013). And last, COVID-19 restrictions greatly impacted the final empirical part of this research regarding measuring the possible effect of the blended learning design on student commute. To meet these challenges, the chosen educational design research (EDR) approach has been pragmatically applied. This pragmatic approach will be discussed using the aforementioned EDR characteristics (Wang, F. & Hannafin, 2005) (Chapter 1).

The first two are about aiming at informing and improving educational practice, grounded in relevant scientific research. Due to the explorative nature of the subject (first three challenges), the emphasis in this PhD research lies on informing educational practice by qualitatively studying the perceptions, motivations and attitudes of the direct educational stakeholders towards making a trip to campus and (blended) learning, and a thorough realist review of existing research. To improve educational practice, the research-based findings are applied in one prototype of sustainable blended learning. The design and implementation of this prototype were both positively and negatively affected by the COVID-19 restrictions. On the positive side, lecturers as well as students experienced various online learning methods in the three months preceding the implementation of the study programme. During this period, the lecturers improved their online teaching skills and the studied perceptions, motivations and attitudes of the involved students were grounded on more experiences and knowledge. On the negative side, the impact of the intended blended design on their travelling could not be measured. This negative effect has been compensated by focusing on a potential attitude change of students toward online learning and commuting.

In EDR, educational improvement and general theoretical knowledge will be achieved through iterative cycles of analysis, design and implementation. Due to time constraints, this design-based research has been limited to only one cycle. The blended design and derived transferrable knowledge would certainly be more refined if multiple cycles had been conducted. Still, the resulting design principles are not only based on this prototype but also on theoretical works (Ellis & Goodyear, 2013; Garrison & Vaughan, 2008; Laurillard, 2013) and 38 empirical studies. Another characteristic of EDR is involving other stakeholders. In the

exploration stage (Figure 1.1), these stakeholders were ICT or sustainability professionals of six Dutch HEIs and students of a Dutch University of Applied Sciences. In the Design and Evaluation Study, the PhD researcher collaborated with a design team consisting of lecturers, one educational expert and two educational ICT experts. The lecturers were also involved in the implementation of the study programme. So, all direct educational stakeholders are consulted and cooperated in this research but only on a small scale and limited to the Dutch situation. Especially the findings regarding student travel behaviour should be treated with caution in other countries. Cultural, economic, and infrastructural circumstances along with available housing facilities likely will affect student travel behaviour. Although a limited number of stakeholders participated in this study, the predominant use of qualitative methods provided in-depth insight into their considerations. On a larger scale, this insight can be validated in a quantitative study.

In EDR, different research methods can be used. To explore the motivations and considerations of the different stakeholders qualitative methods, such as interviews and student focus groups, are conducted. The focus groups were led by a moderator, an expert in sustainable transport policy and all interviews in this research were conducted by the PhD researcher. Besides PhD researcher, she is a lecturer, commuter and ICT expert. This may have introduced some bias in asking the questions, but it helped gain the interviewees' trust and continue to ask questions when necessary. This resulted in interviews that provided deep insights into motivations and considerations. During the implementation of the prototype, the findings of the exploration could be used for the development of a baseline – and final measurement survey, administered to the students of the study programme, to validate some results of the exploration stage and study the influence of COVID-19 restrictions on the attitude of students. To evaluate this prototype, a mixed method approach was conducted in which these surveys were supplemented with student focus groups. During the design of the prototype, the researcher was present at most of the design meetings. Her role was to provide research-based information on blended learning and to develop design principles that corresponded to what practitioners in the design team felt was needed in practice. To support the design team with research-based information, a realist research review is conducted with a pragmatic approach. This entails that the six initial design principles derived from theoretical works are not validated as a whole but in part in 38 empirical studies about blended learning. This has been done because a complex social system such as blended learning cannot be reviewed as a single intervention applied in various contexts. All empirical studies are analysed on how an intervention corresponding with one or more of the initial design principles, triggered underlying generative mechanisms, producing a certain outcome. Since there are very few empirical studies about sustainability-oriented blended learning, the choice was made to initially develop principles for blended learning and then adapt the resulting principles to what is needed for sustainability-oriented education. As the realist review and the design process of the study programme occurred simultaneously, not all of the results of the realist review could be incorporated into the design principles of the prototype.

The final characteristic of EDR is contextuality, that is, connecting the results with the design process and setting. As stated before, the sustainable blended design is only evaluated in one setting, so the consequences of, for instance, a different study phase or subject, could not be incorporated into this design. This has been partly compensated by supporting the development of the design principles through a realist research review of theory and 38 empirical studies, situated in several countries and within different contexts, on aspects of blended learning. Still, the associated student travel behaviour of the design in different contexts has not been studied.

EDR proved to be an adequate methodology to study this innovative subject with all its challenges. It has ensured that this PhD study resulted in an in-depth insight into the considerations of the stakeholders and evidence-informed design principles for blended learning. Despite time constraints and changing circumstances (COVID-19), this PhD research provides a solid foundation for further research.

6.5 Limitations and suggestions for further research

Although inspired by the whole-Institution approach (Kohl et al., 2021; Mathie & Wals, 2022), choices had to be made to limit the scope of this PhD research. This section will address these choices and the results that need more research.

From the Exploration Study (Chapter 2), a picture arises of HE policymakers reluctant to consider online education as a measure to reduce commute-related student travel out of fear to deteriorate the quality of education. After experiencing online learning during the COVID-19 pandemic, this attitude of reluctance may be changed. After COVID-19, blended learning seems to become the new normal in HE (Megahed & Ghoneim, 2022; Ntim et al., 2021). Future research could focus on this attitude change of policymakers and the implications for decreasing student travel.

In the Exploration Study, the choice is made to study student travel behaviour to limit the carbon footprint of a HEI but does not consider on-campus housing in relation to student commute or blended learning. On-campus housing, that is, students living in (non)university residences in the neighbourhood of the HEI, will probably cause less carbon-intensive travelling but will consume more energy and thus carbon emissions than living at their parental home (Caird et al., 2015; Li, X., Tan, & Rackes, 2015). More research is needed on on-campus housing and its implications regarding the HEIs' carbon footprint in different contexts, also taking into account the travel emissions caused by occasionally travelling to their parental home which can be international travel by air (Davies, Jonathan C. & Dunk, 2015; Naderipour et al., 2021). In addition, the influence of a blended learning design on on-campus housing and associated travel behaviour could be studied. For instance, a blended learning design with a consecutive period of on-campus learning in winter causes higher energy consumption in student housing due to higher heating and lighting requirements

and may also lead to more air transportation by international students (Caird et al., 2015). The student travel behaviour and its relation to on-campus learning and having an online alternative is researched in the Travel Behaviour Study (Chapter 3). This was a pre-COVID-19 study and students did not have much experience with online learning. So, as can be observed in the Design and Evaluation Study (Chapter 5), experiencing online learning changed some of their perceptions. The Travel Behaviour Study was situated in the Netherlands with high-quality infrastructure and a strong cycling culture (Belgiawan et al., 2014). Considerations of students to travel to campus or choice of travel mode may be different in other countries with, for instance, safety issues during travelling with public transport or bicycle (Maguire & Morris, 2018; Miralles-Guasch & Domene, 2010). To generalise the findings of the Travel Behaviour Study, validation is needed in different settings and also, applying a quantitative methodology, in a much larger population.

In the Travel Behaviour Study, the scope was restricted to the short-term commuting decisions of students although these are influenced by medium-term decisions on study location and long-term decisions on lifestyle. Several studies mention the influence of digital technology on the lifestyle of younger people (so-called Millennials or Generation Z). For instance, the use of social media and online shopping possibilities affect their travel behaviour (Chen, Li, & Yuan, 2021; Circella, Tiedeman, Handy, Alemi, & Mokhtarian, 2016). This may also affect their travel behaviour to non-study activities during their 'online learning' days. Further research is needed. The realist research review resulted in six pedagogical design principles accompanied by 24 recommendations, which are dependent on the context of the implementation. To assess the usability and theoretical value of this result, future research should validate the application of the design principles as a whole in a blended learning configuration. Although all design principles are essential, one needs more attention and that is Fostering a safe and social learning environment. The forced online learning modus during COVID-19 has led to a negative impact on students' performance and well-being (Raccanello et al., 2022). Several academic studies have researched this impact. A search in Google Scholar with the search term "emotional well-being COVID-19 online learning "higher education" resulted in 44,600 hits (accessed 24 Feb. 2023). The emotional well-being of students has not been explicitly included in Fostering a safe and social learning environment and probably the aforementioned post-COVID-19 studies can add recommendations to fill this gap. Students' emotional well-being did not emerge as an issue during the evaluation of the sustainable blended learning prototype. Probably because it was not an explicit question to the students.

In this PhD research, only one prototype is evaluated. Hence, it is important to treat the findings carefully and to evaluate their applicability in diverse cultural and disciplinary settings for the purposes of generalization and assessment. In part, this has been captured by conducting a realist review to reinforce the validity of the design principles. Iterations of the designed prototype should also consider the modifications to the design principles needed to comply with the sustainability-oriented learning approach. Another issue is that the designed prototype could not be tested as planned due to the COVID-19 restrictions. Therefore, student

travel behaviour as a consequence of the intended design of 1.5 days per week of on-campus learning could not be measured and evaluated. Besides COVID-19 restrictions, there was another impediment to applying the blended design principles and that is the workload model of the lecturers. This workload model is based on traditional face-to-face education and does not take into account the lecturer's coaching during online learning activities. It is recommended to apply an appropriate model during empirical testing of the design principles (Dekeyser et al., 2014).

6.6 Implications for educational policy

This PhD study demonstrates how learning in higher education can be designed to reduce environmental impacts, improve educational quality and strengthen resilience.
During the COVID-19 pandemic, HE experienced the transfer to emergency remote teaching (Marinoni et al., 2020) exposing different kinds of deficiencies in existing infrastructure and teachers' pedagogical skills for online teaching (Watermeyer et al., 2021). HE seems to realise, also having experienced online learning opportunities that it can be more resilient when implementing blended learning (Ntim et al., 2021). In addition, HE aspires to contribute to the SDGs, making it relevant to consider learning not only from an educational but also from a sustainability perspective. The UN Global Action Program mentions the whole-institution approach in priority action area 2: "The entire learning institution needs to be aligned with sustainable development principles, so that learning content and its pedagogies are reinforced by the way facilities are managed and how decisions are made within the institution." (UNESCO,2020, p.28). When a HEI wants to adopt such a whole-institution approach they should consider the environmental impact of a learning design. As shown, commute-related student travel has a high impact on an institution's carbon footprint. This impact may be less when learning is scheduled on one or two days per week. This has more advantages. The student participants in this research stated that the scheduling of their on-campus education affects their decision to travel to campus, also confirmed by other research (Moores et al., 2019). Students sometimes skip a learning activity on campus when there is only one on a given day or late in the afternoon. When clustering learning on one or two days per week, it may be possible that this increases attendance rates. This clustered on-campus learning is only feasible when accompanied by online learning in a blended learning design. In this research, pedagogical design principles are developed to enhance the quality of this design. The situation of students being less on campus and more at home poses several challenges in terms of their self-regulation skills, community building and interaction possibilities. Three design principles meet these challenges and are accompanied by recommendations (RC1 up to RC15) for actions on how to deal with these challenges (Table 4.6). Other design principles are about learning activities, that is, learning through acquisition and inquiry, discussion, practice and collaboration. Although each of these activities has its own recommendations (Table 4.6), to enforce each other they should be combined into one design.

 All recommendations are distilled from 38 empirical studies about implementations of one

or more of the six design principles. When designing sustainable blended learning, the design principles and associated recommendations can be used as a list of focal points to assess the pedagogical quality of the design, noting that some recommendations are only applicable in a certain context. A blended learning design can stimulate sustainability-oriented learning. For instance, a blended design can allow students to use the virtual space for inter- or transdisciplinary collaboration at a place and time of their choice without the cost and environmental impact of travel. Another opportunity lies in personalising the learning content to the needs of the student. Multi-media content delivery and assignments that both meet the learning preferences encourage students to acquire knowledge and skills online while in-class sessions can be used for discussion and (peer) feedback, developing intrapersonal competency or self-awareness.

The six design principles were also evaluated during the design and implementation of a minor at Avans University of Applied Sciences. This minor took place during the COVID-19 pandemic and after a period of emergency remote teaching. Lecturers as well as students experienced the possibilities of online learning for about four months before the minor started and also, for the most part during the minor. This seems to have changed the students' attitude towards online collaboration. In the Travel Behaviour Study (before COVID-19) the students agreed on the potential of online learning for content acquisition but not for collaborative activities. These should be carried out on campus. The minor students on the contrary assessed the online collaboration meetings as more productive than on-campus sessions. This may influence their motivation to travel to campus to attend collaborative activities and reinforces the need for clustering education on a few days to make learning on campus worthwhile for the students. The evaluation of the blended learning minor also demonstrated the need for adapting the lecturer's workload model while applying blended learning. This workload model should acknowledge the time and effort needed to coach the students during their online activities.

This study showed the potential of blended learning to decrease HEIs' carbon footprint and enhance educational quality including sustainability-oriented learning. Therefore, we suggest designing high-quality and low-carbon blended learning by applying the developed pedagogical design principles and cluster on-campus education one or two days per week.

Summary

Introduction

Higher Education (HE) has a crucial role in realizing the Sustainable Development Goals (SDGs), the 2030 agenda of the United Nations to transform the world to be more resilient and sustainable. HE is part of a wide stakeholder community and thus can transmit and address sustainability challenges not only through education but also through institutional transformation. This requires a whole-institution approach, embedding sustainability in all aspects of the institution. This PhD research is a step in the direction of this whole-institution approach by considering learning and teaching from an environmental and educational perspective.

(International) travel of staff and students to commute or attend conferences or meetings is one of the main contributors to the carbon footprint of a higher education institution (HEI). This thesis focuses on the most frequent travel, namely, the local commute of students to and from a HEI. It explores the possibilities to decrease this commute through a different educational organisation, using digital technology. Previous research has shown that distance-based HE teaching models achieve large carbon reductions compared to on-campus models, but whether this is also applicable to a blended form of these models needs more study.

The effectiveness of, for instance clustering on-campus education on one or two days per week supplemented with online learning, for reducing travel emissions depends on the travel behaviour of students, commuting to and from campus. A student's attitude toward learning on campus or online will probably affect their decision to make a trip to campus. According to the Theory of Planned Behaviour, also their social norms and perceived behavioural control are influential. In addition, the chosen travel mode determines the amount of travel emissions.

In addition to lowering the carbon footprint, a blended design must maintain or ideally improve educational quality. Having a virtual space alongside a physical space, as in blended learning, changes or extends the mode of interaction with fellow students, lecturers and content. Pedagogical guidelines are needed and were developed, on how to make use of the possibilities of these spaces to enhance educational quality. In this PhD study, the acquisition of sustainability competencies by the students is considered one of the aspects of educational quality. This PhD research aims to find directions on how to design learning in higher education from both a sustainability and an educational perspective. The potential of a blended learning design to reduce the carbon footprint of a HEI by decreasing commute-related student travel will be studied. This design should not compromise the educational quality and support sustainability-oriented learning. The central question is: How can sustainability-oriented blended learning in higher education be designed to reduce carbon emissions due to student travel behaviour without compromising educational quality?

The following sub-questions guide this research:

1. What impact could the adoption of online learning in (Dutch) higher education have on decreasing its carbon footprint through reduced student commuting, and on educational quality?
2. What are the considerations and (de)motivators of students influencing their travel mode choices and their decisions whether to travel to their institution or to study (online) from home or a place that does not require travelling?
3. Which design principles and recommendations can be extracted from scientific theory and empirical studies about blended and sustainability-oriented learning?
4. How can a sustainable blended learning study programme be designed and implemented in higher education?

The COVID-19 pandemic in 2020 severely impacted HE and also the design and implementation of the sustainable blended study programme (RQ4). The government restrictions changed the intended blend to mainly online education. The empirical part of this research is situated in the Netherlands and mainly at Avans University of Applied Sciences. This university has a wide range of bachelor studies and a large number of students divided over three cities.

Methodology

The used methodology to conduct this PhD research is based on Educational Design Research (EDR) (McKenney and Reeves, 2018). EDR aims at both scientific and practical solutions and is well-suited to deal with a complex reality such as a blended learning intervention. This research applied a pragmatic approach due to time constraints and changing circumstances. The three stages of EDR to design the sustainable blended intervention, Exploration, Construction and Reflection, have all been completed but not with the required iterations of the Construction and Reflection stage for testing and refining. Due to a relatively unknown research area, the Exploration stage has been extended, answering research questions one and two. In addition, instead of testing and refining the developed prototype in different contexts, a thorough realist synthesis review of theoretical and empirical studies was conducted to support the development of the pedagogical design principles. In all stages, various research methods were applied. In the Exploration stage, mainly qualitative methods were used to gain an in-depth understanding of the considerations and motivations of the different stakeholders. In the Construction stage, qualitative methods were supplemented with a realist synthesis review and, a mixed method approach was conducted during Reflection.

Results

Exploration stage

Due to the study of Caird et al. (2015), it was known that distance-based HE teaching models achieve large carbon reductions compared to on-campus models at the start of this PhD research. In addition, the largest contributor to these carbon emissions proved to be education-related student commuting. In the Exploration stage of this PhD research, this problem and possible solutions were explored further. First, Dutch reports and academic studies, situated in other countries, on the carbon footprint of a HEI were studied to compare the impact of student and staff commute. The results confirmed the findings of Caird et al. (2015). A possible solution to lower the large contribution of travel emissions could be an educational organisation in HE in which online learning would substitute on-campus learning for at least 30 per cent. This solution was presented to ICT and sustainability professionals of several Dutch HEIs to explore its viability. This showed that only a few professionals recognized the potential of online learning to lower carbon emissions due to education-related travelling and their reactions were twofold. On the one hand, there were concerns about deteriorating educational quality by this measure and on the other hand, online education professionals in particular saw the benefits of a blended form of online and on-campus education such as personalising education to the students' needs and extending the learning environment with digital media.

Next, the possible effect of blended learning on the travel behaviour of students was explored. Five focus groups were held with Dutch students of different bachelor studies and study phases. Their perceptions, attitudes and preferences regarding their travel mode and the decision to make a trip to campus were analysed and described. Their travel mode choice is mostly based on habit and influenced by travel-regulating measures of the Dutch government (a free public transport permit) and HEIs (high parking costs). These measures ensure that Dutch students, in most cases, opt for a low-carbon travel mode such as a bicycle or public transport to travel to and from the HEI. Their decision to make a trip to campus seems to be a reasoned choice corresponding to the Theory of Planned Behaviour, influenced by the number and time of the day of their scheduled classes, the type of learning activity and their perceived study abilities. This decision process was outlined in a conceptual model Travel for Learning. In contrast to the educational professionals, the students showed a positive attitude towards substituting on-campus learning with online activities such as lectures or self-study for approximately three days per week. Practice classes and collaboration activities were considered important to attend on campus. Increased travelling to non-study activities on the online learning days depends on the opportunities and social contacts in their immediate residential area.

In conclusion, decreasing student commute through online learning is viable only if educational quality is not compromised (according to educational professionals) and, the learning activities that require interaction with a lecturer or fellow students are still performed

on campus (according to the students).

Construction stage

To address the concerns of the stakeholders, pedagogical design principles for sustainable blended learning were developed in two different approaches, that is, through realist synthesis research (Chapter 4) and, the design of a prototype by a team of educational developers supported by the researcher (Chapter 5). A pragmatic approach to the realist synthesis research method resulted in six key design principles with associated recommendations for blended learning. The key principles are grounded in three theoretical frameworks, that is, the Conversational Framework of Laurillard (2013), the Community of Inquiry Framework of Garrison and Vaughan (2008), and, as we framed it, the Integrative Relational Framework of Ellis and Goodyear (2010) and evaluated through a review of 38 empirical studies. The resulting principles are evaluated and adapted to what is needed for supporting the development of sustainability competencies. The key principles are (with sustainability-oriented adaptations in italics):

1. Aiming at self-regulation (and self-awareness) of learning and practice in the student's learning process.
2. Fostering a safe and social learning environment.
3. Facilitating (a)synchronous interaction and discussion among fellow students and with the lecturer to stimulate reflection and critical thinking.
4. Transforming learning through acquisition and inquiry into an active process based on existing knowledge (in which new knowledge is constructed to contribute to sustainability).
5. Working on authentic (and action-oriented) tasks with scaffolded and theory-based practice meeting the learning preferences of students.
6. (Inter/transdisciplinary) Collaboration for constructing a shared outcome through participation and negotiation with fellow students in a technologically enhanced learning environment.

The sustainability-oriented adaptations were applied after the design process of the prototype. Therefore, the prototype is developed based on design principles only for blended learning but with a sustainable organisation of on-campus learning and teaching scheduled for 1.5 days per week.

Reflection stage

The developed prototype, a study programme (minor) of one semester, was implemented

during the COVID-19 pandemic. Therefore, on-campus learning and teaching were diminished to half a day per two weeks, making it impossible to measure student travel emissions as a result of the original design. Instead, a possible attitude change of students toward online learning and commuting that may have been caused by going through a period of primarily online learning due to COVID-19 restrictions was studied. The cognitive, behavioural and affective processes leading up to this attitude change are explored through a survey at the start of the minor. This survey was part of a mixed method approach to evaluate student travel behaviour and the implementation of the design principles. The experiences of lecturers as well as students were included in this approach. The evaluation showed the relevancy of all design principles. Focus on self-regulation skills is needed, according to the lecturers, although students experience this differently. Creating a safe and social learning climate for a group of approximately 30 students needs more activities when having mainly online meetings. This is partly compensated by collaborating in a team of four students. Social activities even as coaching and stimulating online discussions were not implemented because the used workload model for lecturers was not suitable for allocating unscheduled online activities. A mainly online organisation was at the expense of the interaction possibilities with fellow students but did not interfere with the interactions with lecturers. The guest lecturers by professionals and conducting research assignments were activating and appreciated by the students. These research assignments were mostly carried out in a team and motivated the students as they worked on real-world issues, creating value for stakeholders.
Experiencing online learning and less travelling may have been a trigger for an attitude change in students. Through this experience (behavioural process) they know that online meetings can be productive and less time is lost in travel (cognitive process) and both were appreciated by the students (affective process).

Discussion

This research adds a sustainable perspective and a step toward a detailed pedagogical framework to what is already known about blended learning. The notion that a blended learning design can be used to decrease the carbon footprint of a HEI by reducing education-related student commute is not common knowledge. Although we could not measure the impact of a blended learning design on student travel emissions due to COVID-19 restrictions, there are strong indicators that it would make a difference. Firstly, there are no strong indicators that the online learning periods will increase their travelling to non-study activities. Secondly, the study of the travel behaviour of students showed their attitudes, perceptions and preferences that influence their motivation to travel to campus. Most student participants welcome the thought of a learning schedule of one or two days per week, supplemented with online learning and thus having to travel less. Thirdly, their motivation to travel depends on the type of learning activity. In the study before COVID-19, the participating students

stated that high interaction activities, such as collaboration and practice, need an on-campus environment but after COVID-19 and experiencing a period of online learning, they also appreciated the effectiveness of online meetings. A student's motivation to attend particular learning activities is also dependent on their study abilities. In summary, having an online alternative to on-campus learning will probably influence the student's decision to travel to campus. This decision process was conceptualised in the model Travel for Learning. The environmental impact is dependent on the distribution of learning activities over online and on-campus days.

This distribution should be carefully designed listening to the preferences and concerns of the educational stakeholders. Therefore, pedagogical design principles were created to guide the development of a blended learning unit. These design principles seem general and important for all kinds of education but these principles are crucial for a blended form in which students have more freedom to determine where and when to study. They need self-regulation skills and additional motivation to perform their learning activities. This motivation can be enhanced by using the capabilities of having a virtual space next to a physical space and by fostering bonding among students and with the lecturer.

According to the whole-institution approach, sustainability should be embedded in the organisation as well as in the pedagogical approach of a blended learning design. Blended learning has at its disposal, as stated before, an additional virtual space. This space can be used to collaborate and interact with students from different disciplinary, national and cultural backgrounds together at a place and time of their choice to create interpersonal competency without the environmental and financial costs of travel. The World Wide Web provides numerous resources to consult but students need critical thinking skills to find reliable knowledge and to process it into new knowledge which contributes to sustainable change.

Reflections on Methods

Our approach to the EDR methodology proved to be well-suited for this PhD research, aiming at finding directions on how to design learning in higher education from both a sustainability and an educational perspective. This aim aligns well with the focus of this methodology, which is finding pragmatic solutions for complex situations, such as the design of blended learning, grounded in scientific research. This pragmatic methodology allows for applying different research methods. The applied qualitative research methods in the extended exploration stage delivered in-depth insight into the considerations and motivations of various educational stakeholders. In addition, the current knowledge regarding student travel behaviour, online learning and the carbon footprint of a HEI was studied. This clarified the problem and showed the potential of blended learning. During the construction and reflection stage, a realist research review and a mixed method approach assessed the viability of this solution, namely, the design and implementation of a sustainable blended study programme. Nevertheless, two remarks have to be made. The first concerns the iterative cycles of analysis, design and implementation, which EDR prescribes for refinement purposes

and the generation of general knowledge. In this PhD research, only one prototype has been designed and evaluated. The second concerns the involved research population. This research was situated in the Netherlands. Student travel behaviour will probably be different in more car-dependent countries such as the United States or Australia. In addition, this was a small-scale research project involving a limited number of stakeholders.

Recommendations

This PhD research is largely exploratory in nature because not much is known about the relationship between student travel behaviour and blended learning to reduce the carbon footprint of a HEI. Nevertheless, it produced educational policy recommendations that show promise for improving educational quality and reducing the carbon footprint. In addition, there are a number of recommendations for further research, the most important of which are mentioned below.

For educational policy of higher education:

1. Schedule learning and teaching for one or two days per week on campus with highly interactive activities. This will lower the environmental impact of learning and teaching and will probably increase the attendance rates of students.
2. Use the pedagogical design principles to assess the educational quality of the design.
3. Use the recommendations associated with the design principles as propositions for the design of a blended learning configuration. These recommendations are dependent on the context, for instance, the study phase and subject.
4. Combine the different online and on-campus learning activities in such a way that they enforce each other.
5. Change the workload model of lecturers to a model appropriate for unscheduled coaching during online learning activities
6. Raise awareness among the students of the environmental impact of travelling by sharing that one of the reasons to limit on-campus education to a few days is that the institution aims to lower its carbon footprint.

For academic research:

1. A design-based research needs iterations of the construction and reflection stage to generate transferrable knowledge. Therefore, the design principles and recommendations should be applied and studied in various contexts for refinement purposes and knowledge generalisation.
2. Because of the COVID-19 restrictions, the actual travel emissions

due to commute-related travel of the blended design could not be measured. To measure these emissions and validate the in-depth insight offered, a quantitative study of the student travel choices to attend on-campus learning of a large student population is recommended.

3. Having to travel less to and from campus may have an effect on the chosen travel mode of (Dutch) students. More research is needed.
4. To generalise the findings of the Travel Behaviour Study, validation is needed in different settings/countries.
5. The impact of on-campus housing on the carbon footprint of a HEI is not considered and should be compared with the impact of student travel.

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