ONE CLASS, TWO WORLDS

Understanding transactional distance in hybrid learning

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Eén klas, twee werelden: Inzicht in transactionele afstand bij hybride leren

Proefschrift

ter verkrijging van de graad van doctor aan de
Universiteit Utrecht
op gezag van de
rector magnificus, prof. dr. ir. W. Hazeleger,
ingevolge het besluit van het College voor Promoties
in het openbaar te verdedigen op

woensdag 4 februari 2026 des middags te 2.15 uur

door

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geboren op 28 februari 1997
te Den Haag

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Chapter 1 Introduction

1.1   Hybrid education

The world is increasingly shaped by technological developments, which have transformed the ways in which we teach and learn. These innovations have opened up new possibilities for education, allowing students and teachers to interact across physical and digital spaces in ways that were previously impossible. One of the most visible applications of these developments is online education, which became particularly relevant during the COVID-19 pandemic when physical classrooms were inaccessible or downright illegal. The rapid shift to fully online teaching highlighted both the opportunities technology provides and the challenges of keeping students engaged and connected in a purely digital environment. In an online environment, students and teachers are physically separated, and learning takes place primarily through digital platforms. Electronic learning environments allow students to watch pre-recorded lectures, complete assignments online, and interact asynchronously with their peers and instructors, highlighting the potential of technology to support flexible learning. As the emergency of fully online education receded, educational institutions increasingly adopted hybrid education, which blends onsite and online learning in real time. In hybrid education, students are physically present in the classroom, while others join synchronously online, creating a dual learning environment. It is important to note that "hybrid education" is not uniformly defined in the literature. Different studies and institutions use varying criteria to describe what constitutes hybrid learning, ranging from occasional online components in otherwise onsite courses to fully integrated dual-mode teaching (Irvine, 2020). In this dissertation, hybrid education is operationalized specifically as real-time synchronous instruction in which students participate onsite while others join online, enabling a dual learning environment. While hybrid education offers flexibility and inclusivity, it also introduces unique challenges for teaching and learning. Teachers must simultaneously manage multiple student groups, balancing attention and engagement between online and onsite learners. Students may experience barriers to student-student interaction and student-teacher interaction, which can influence student engagement, motivation, and learning outcomes. These challenges raise important questions about how instructional design, interaction patterns, and social presence operate in this dual setting.

1.2   History of hybrid education

Both hybrid and online education became a widespread practice due to social distancing policies implemented during the COVID-19 pandemic, as many educational institutions were searching for ways to have at least some of their students attend onsite classes, whilst catering to the full student complement. However, various forms of distance education have existed for well over a century, long before the pandemic reshaped the educational norms. A recent publication traces the origins of distance learning back as far as 1728, when an advertisement from Caleb Phillips was placed in the Boston Gazette advising that any "Persons in the country desirous to learn this art [a new method of shorthand], may by having the several lessons sent weekly to them, be as perfectly instructed as those that live in Boston" (Sleator, 2010, p. 320). However, correspondence courses in the more modern sense of the word did not take off until the 19th century, facilitated by the development of modern postal services. One of these correspondence course was the Pitman shorthand training, established in 1852 (Matthews, 1999). Not all correspondence courses were focused on secretarial skills. By 1923, the international correspondence school targeted iron miners and railroad workers and had a total of 2.5 million enrolled students. By the 1920s, emerging technologies began transforming the landscape of correspondence courses (Moore & Kearsley, 1996). Radio and television allowed distance educators to go beyond text-only material (Simonson et al., 2011). For instance, in 1923, more than 10% of all broadcast radio stations were operated by educational institutions, providing educational programming to their audiences (Casey, 2008).

A new technological advancement led to another form of distance education. By 1963, the Federal Communications Commission in the United States created the Instructional Television Fixed Service, a set of 20 television channels designated for use by educational institutions. (Reisslein et al., 2005). In 1970, Stanford University introduced an early form of hybrid teaching by broadcasting lectures from one hall to screens in other lecture halls (Pettit & Grace, 1970). After 1990, multiple open universities used distance education platforms (mail, television, taped recordings) to make higher education more accessible to the public. In these times students either had to travel to campus or chose these correspondence learning opportunities, however, this had very limited student-teacher and student-student interaction (Daugherty & Funke, 1998). While correspondence learning served as a viable option for some, its lack of interpersonal engagement hindered the learning experience for others. After the invention

of the world wide web, in 1993 the first web-based, online instruction was launched (Sleator, 2010). These types of fully online programs remain prevalent in today's society. For example, the Netherlands' own Open Universiteit allows students to obtain Bachelor's and Master's degrees entirely online. Additionally, many universities worldwide offer online courses, such as Massive Open Online Courses (MOOCs), which are widely known for their accessibility. The emergence of online learning alleviated some of the earlier barriers; however, even in the digital age distance persisted as a challenge due to the predominantly asynchronous nature of online interactions (Angiello, 2010). The concept of hybrid education, combining online and onsite learning at the same time (synchronously), has its roots in the 1970s. However, it was only in the 2000s that hybrid education gained broader recognition and application. For example, Lakhal et al. (2021) used hybrid education to provide education both for the students who lived close to campus and for students who lived too far away from campus to commute. Their study has also implied that interaction is something that might be harder to achieve in a hybrid setting but, with some extra preparation, is possible (Lakhal et al., 2021). Which brings us back to the covid-19 pandemic, during which both online and hybrid education saw a significant rise in popularity. The pandemic not only accelerated the adoption of hybrid education but also sparked a surge in research on its effectiveness. While previously more common in countries with vast geographical distances, hybrid education became increasingly relevant even in smaller nations, valued for its flexibility and ability to facilitate teaching while adhering to COVID-19 restrictions.

1.3   Why hybrid?

Nowadays, there are several reasons why teachers may opt for hybrid education, one of the most significant being the need to overcome geographical distance. A prime example is the study by Lakhal et al. (2021) conducted at a university in Montreal, Canada. Their hybrid program enabled students living outside Montreal to participate in courses online, while those residing closer to campus attended classes in person. Students were assigned to either the online or onsite mode, rather than being given the choice. This study specifically focused on the following aspects: pedagogy, technology and organization. The findings emphasized the importance of structured course design and planning to ensure effective learning experiences. However, ICT-related challenges sometimes hindered online students' inclusion and negatively impacted teaching. Despite these challenges, students appreciated the flexibility and accessibility that the hybrid format

provided (Lakhal et al., 2021). Due to Canada's vast geographical scale, hybrid education is an effective solution for ensuring students outside major cities still have access to higher education.

Similar trends can be observed in other large countries, including Australia, China, and the United States, where hybrid models help bridge geographical gaps in education (Bower et al., 2015; Szeto, 2015; Zydney et al., 2018). Bower (2015) also implemented hybrid education for similar reasons, as it provided both flexibility and accessibility. At the same time, it allowed students to engage in real-time collaborative learning activities, demonstrating the potential of hybrid education to enhance both inclusivity and engagement (Bower et al., 2015).

Another reason for implementing hybrid education is to optimize campus resources and teaching efficiency. This approach is used at KU Leuven, where hybrid education is applied in a remote classroom setting. In this model, one group of students attends the course in person, while another group follows the same session from a different campus (Raes et al., 2020). This method reduces the need for multiple course repetitions, allowing students across campuses to participate simultaneously, thus maximizing the efficient use of teachers' time. I personally encountered a similar situation during the COVID-19 pandemic, when I was asked to teach a course at the PABO (primary preservice teacher training). Due to restrictions on the number of students allowed in the classroom, all groups were split in two, requiring teachers to deliver the same lesson twice. However, logistical constraints made this impractical. As a solution, the course was delivered in a hybrid format, where half of the students attended in person while the other half joined via an online environment. This setup ensured that both groups received instruction simultaneously without doubling the teaching workload. It is important to note that KU Leuven's hybrid model was implemented before the COVID-19 pandemic, demonstrating that hybrid education is not just a temporary solution but a long-term strategy for increasing accessibility and efficiency in higher education.

Several publications highlight the benefits of hybrid education in cases where students need to balance work and studies. One example is teacher education, where students often have to balance their school work with their university studies (Lakhal et al., 2021). In the latter study, participants appreciated the flexibility of hybrid education, as it allowed them to work during the day and attend evening classes without the added burden of commuting between work, home, and university. Other studies have

identified additional circumstances where hybrid education enhances accessibility. For instance, it provides a valuable solution for students who are caregivers or have chronic illnesses, enabling them to participate in education without losing opportunities for interaction with both onsite and online peers (Bower et al., 2015; Raes, 2022; Szeto & Cheng, 2016; Zydney et al., 2018). Moreover, similar to Raes (2020), hybrid education also benefits teachers by reducing the need to deliver the same course separately in both fully online and fully onsite formats, streamlining their workload while maintaining student engagement.

1.4   Pitfalls of hybrid education

While hybrid education offers significant benefits, it also presents some challenges that must be carefully addressed. A first challenge has a technical character: in hybrid learning, the quality of video and audio is a critical aspect, as both are essential for effective communication and student engagement. Kassandrinou et al. (2014) emphasized that high-quality two-way audio enhances the natural flow of communication and increases the sense of co-presence among students. However, even with excellent audio quality, there can still be delays in transmission, which complicates communication, particularly for online learners (Bower et al., 2015). To mitigate such issues teachers often rely on lower-bandwidth tools, such as chat functions, rather than video, as these tools are less likely to experience disruptions if there are connection problems (Lidstone & Shield, 2010; Vu & Fadde, 2013). While good quality audio and video are essential for hybrid education, multiple studies have shown that they significantly impact the students' learning experience (Bower et al., 2015; Wang et al., 2017; Zydney et al., 2018).

In addition to the technological challenge of ensuring optimum audio and video connections, a second challenge, inherent to hybrid education, concerns time-management: instructors must constantly juggle multiple roles. Beyond teaching and classroom management, they also need to operate the technological setup and attend to the needs of both online and onsite students simultaneously (Wang & Huang, 2024). This leads to teachers having to split their focus between two distinct groups, which can lead to feelings of being overwhelmed. In some cases, onsite students have reported that teachers were overly focused on the online learners, which led to online students feeling scrutinized while onsite students felt neglected (Raes, 2022; Szeto & Cheng, 2016). Conversely, some educators, in an attempt to balance their focus, may adopt a slower pace and repeat content, which can negatively impact the experience for onsite students (Bower et al., 2015;

Szeto & Cheng, 2016). There are also instances where teachers find it difficult to fully engage with online students, and may even forget their presence altogether (Lakhal et al., 2021; Wang et al., 2017). Such discrepancies in engagement can lead to diminished learning outcomes for both groups (Wang et al., 2017).

A third significant challenge is the potential lack of interaction between participants, which is crucial for student engagement and learning. Interaction in a classroom setting is multifaceted, involving both verbal communication (dialogue) and non-verbal cues (such as body language) (Bambaeeroo & Shokrpour, 2017; Howe, 2023). Research has consistently shown that students who actively engage in discussions and interactions exhibit better communication skills, heightened motivation, and improved learning outcomes (Rocca, 2010). Moore (1989) identified three types of interaction that are critical in the classroom: student-teacher (S-T), student-content (S-C), and student-student (S-S) interactions. Ideally, all three forms of interaction should be fostered at a high quality to ensure an effective learning environment (Moore, 1989). This becomes particularly challenging in hybrid and distance education settings, where face-to-face interaction is limited (Szeto & Cheng, 2016). A comprehensive approach, as suggested by Szeto and Cheng (2016), involves incorporating a more dynamic model of interaction that includes not only these three interaction types but also a fourth category: instructor-content interaction.

In the case of S-T interactions, both teachers and students have reported that online learners are either ignored or overly focused on, leading to an imbalance that affects the learning experience. Online students may feel scrutinized, while onsite students may feel neglected (Lakhal et al., 2021; Wang et al., 2017). Additionally, online students have been shown to be more likely to interact with teachers, while onsite students tend to engage with their peers (Szeto & Cheng, 2016). For S-C interactions, online students often have the same access to materials as onsite learners, especially when resources are made available digitally. However, in subjects like mathematics and physics, the use of black- or whiteboards for explaining formulas can disadvantage online learners, as they may not be able to view the board as clearly as their onsite counterparts (authors, 2025). Furthermore, hybrid education may restrict S-S interactions by isolating students into two distinct groups, onsite and online, leading to minimal interaction across groups.

In short, the main challenges of hybrid education include the technical demands concerning audio, video, and connection quality, as well as the

pedagogical challenges of teachers needing to divide their attention between online and onsite students and facilitating meaningful interaction across different student groups. To address these challenges effectively, it is essential to adopt a theoretical lens that can help make sense of how interaction patterns, engagement, and communication are influenced in hybrid settings. One such lens is Moore's theory of Transactional Distance, which provides a framework for understanding the psychological and communicative gaps that may arise between teachers and students, as well as among students themselves.

1.5   Transactional distance as a theoretical lens

The concept of transactional distance was first introduced in the 1970s within the context of distance education (Moore, 1973). The term transaction refers to the exchange of ideas, experiences, and various forms of knowledge between teachers and students, or among students (Moore, 2018; Zhang, 2003). Meanwhile, the concept of distance relates to the perceived barriers, whether physical, emotional, or psychological, that arise during these exchanges.   Moore (1993) defined TD as "a psychological and communications space to be crossed, a space of potential misunderstanding between the inputs of instructor and those of the learner." (Moore, 1993, Page 22) Transactional distance has come to be understood as the psychological and emotional gap between teachers and students, as well as among students themselves (Moore, 2018). According to the theory, greater transactional distance indicates higher perceived barriers to effective communication and understanding. Transactional distance is influenced by a variety of factors including physical separation, isolation, differences in communication methods, and the structure of the learning environment. When students perceive a greater transactional distance, it often leads to reduced engagement (Bolliger & Halupa, 2018). Consequently, a higher transactional distance can negatively impact the learning experience, while a lower transactional distance promotes engagement, resulting in more positive outcomes.

Moore (1973) identified three key factors that influence transactional distance: dialogue, structure and autonomy. *Dialogue* refers to intentional communication that increases learning between the teacher and students, as well as among students. Greater dialogue reduces transactional distance, while less dialogue increases it. Conversely, *structure* refers to the degree of rigidity or flexibility in the course design, including organization and instructional methods. A more rigid structure limits flexibility and often reduces dialogue leading to a higher transactional distance. Moore defines

structure as the extent to which a course content and processes are pre-determined and inflexible, dictating the learning experiences. Since dialogue and structure are inversely related, a highly structured course tends to limit dialogue and thus increase transactional distance. The concept of *autonomy* in the theory relates to the level of independence a student needs when there is a certain amount of transactional distance. Autonomy refers to the student's ability to take responsibility for their own learning, including setting goals, managing time, and making decisions about their learning process. When transactional distance is high, students are required to exercise a greater autonomy, as there is less dialogue and more independence. Conversely, when transactional distance is low, students rely less on their autonomy due to the increase in interaction and dialogue. Students who prefer working independently might favor environments with a higher transactional distance, where greater autonomy is required.

Although the theory of transactional distance has evolved over the years, particularly with the inclusion of the student perspective through the variable of autonomy, and an expansion from focusing solely on S-T interactions to also considering student-student S-S interactions, it remains highly relevant today. A recent review concluded that, due to the rise of online and blended education, the theory continues to serve as an essential framework for teaching in these settings (Xiao, 2024). However, it's not only the theory itself that has evolved over the years; the methods for measuring transactional distance have also advanced. What initially began with students rating the amount of distance they perceived has now developed into more comprehensive approaches, such as providing students with questionnaires that assess all three types of interaction: S-T, S-S and S-C (Paul et al., 2015; Xiao, 2024; Zhang, 2003).

To operationalize the insights of transactional distance and better manage interactions in hybrid classrooms, we build on the framework by Szeto and Cheng (2016) to propose a guiding model of interaction within hybrid education (Figure 1.1). In this new model, the content is positioned between the two learning spaces, allowing materials such as presentations to exist in both environments simultaneously. We assume that the teacher remains in the physical classroom, while students may be present either onsite or online. Compared to Moore's original model, which identified three types of interaction, our framework significantly expands the scope of interaction, incorporating eight distinct interaction types: student online – student online, student online – teacher, student online – student onsite, student online – content, student onsite – student onsite, student onsite –

teacher, student onsite – content and teacher – content. This framework acknowledges the complexity of hybrid learning environments, where interactions go beyond the traditional classroom.
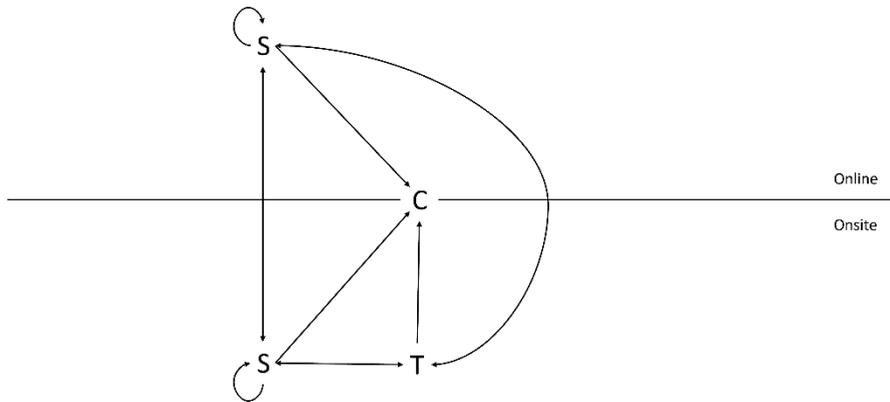
Figure 1.1 *Hybrid Education Interaction Model (HEIM). Guiding framework designed to represent the different types of interaction that can take place in a hybrid lesson. C stands for content, S stands for students and T for teacher.*

1.6   Knowledge gap

Although research on hybrid education has accumulated in recent years, important questions remain unanswered, particularly regarding how the practical and theoretical challenges of hybrid learning can be addressed. While hybrid education combines synchronous online and onsite instruction, it introduces a set of pedagogical, technological, and social challenges that differentiate it from both fully online and traditional onsite learning. Despite its growing prevalence, the mechanisms through which these challenges impact student engagement, interaction, and learning outcomes remain poorly understood, highlighting a clear practical knowledge gap: we do not yet know how to effectively manage teacher attention, foster interaction, and ensure equitable learning opportunities for both online and onsite students in hybrid environments. In addition to this practical gap, there is also a theoretical gap concerning the applicability of TD theory in hybrid education. While TD has been widely studied in fully online and distance education settings, it has been less extensively applied to hybrid environments, and its potential to guide solutions to hybrid-specific challenges is largely unexplored. Existing studies often treat online and onsite students as a single group, obscuring the nuanced differences in their experiences. For instance, Murray et al. (2021) compared transactional distance across online, hybrid, and onsite education but analyzed all students together, without distinguishing between those participating onsite versus

online. This methodological choice limits our understanding of whether transactional distance operates differently for online and onsite learners within the same hybrid classroom, leaving a gap in both theory and practice (Murray et al., 2021). Similarly, other studies have noted the unique challenges of hybrid education, such as teachers managing dual modes of instruction simultaneously, students hesitating to participate due to technological or social barriers, and uneven engagement between groups (Bower et al., 2015; Raes et al., 2020; Szeto & Cheng, 2016). Yet, these investigations often use TD as a supporting framework rather than critically exploring how dialogue, structure, and autonomy manifest in hybrid contexts, reinforcing the need to revisit the theory for this setting. Taken together, these insights point to the dual knowledge gap that motivates the current dissertation. First, we lack practical strategies to address the complex challenges of hybrid education, including teacher time management, equitable attention allocation, and meaningful student–student and student–teacher interactions. Second, we lack a theoretical understanding of how TD functions in hybrid classrooms, particularly when online and onsite students may experience engagement, interaction, and communication differently. By systematically examining these gaps, the present study aims to provide both practical guidance for managing hybrid learning and theoretical insights into the adaptation of TD theory to this increasingly common educational context.

Given the distinct dynamics within hybrid education, we hypothesize that transactional distance theory may not fully apply in the hybrid environment as it does in fully online or distance education. By further investigating how transactional distance unfolds in hybrid education, future research can offer new theoretical insights and practical strategies for optimizing student engagement and instructional effectiveness in these increasingly common learning environments.

1.7   Overview of dissertation

The overarching goal is to explore the practical challenges that occur during hybrid education and how we can overcome these challenges. Moreover, we also aimed to explore the role of TD in hybrid education and how it impacts interaction, engagement and learning experiences for both online and onsite students. To explore this the following research questions will be addressed in the chapters of this dissertation.

1. What were university teachers' experiences with hybrid education during the COVID-19 pandemic?

2. How does transactional distance develop during a hybrid university course setting and how does this affect the interaction between the online and onsite students during this course?
3. How and to what extent can transactional distance theory be applied to hybrid education?
4. How do interaction patterns and learning experiences unfold for students and teachers in a hybrid COIL setting?

The first research question is addressed in **Chapter 2**, which presents a qualitative interview study with teachers, from the science faculty, about their experiences with hybrid education during the COVID-19 pandemic. The data were analysed using a top-down meets bottom-up approach, incorporating both literature-based codes and emerging themes from the interviews. This study explores teachers' experiences, identifying positive aspects, pitfalls, areas for improvement, and how hybrid education differs from both their traditional and online teaching methods. Insights from this chapter highlight the practical challenges teachers face in hybrid settings and inform the development of strategies to support effective teaching across multiple modalities.

The second research question is examined in **Chapter 3**, which presents a case study of a history of physics course that was taught in a hybrid format for practical reasons. This study analyses four recorded lectures using turn-taking analysis to visualize how interactions unfolded between online and onsite students. Additionally, after each lecture, students completed a questionnaire measuring their transactional distance during that session. To further triangulate the findings, students and teachers were interviewed about their general experiences, the differences between online and onsite students, and their perceptions of teacher-student and student-student interactions. This chapter offers a detailed, data-driven look at the micro-level dynamics of hybrid classrooms, illustrating how interaction patterns vary depending on student location and engagement.

The third research question is explored in **Chapter 4**, which presents a systematic literature review on the role of transactional distance theory in hybrid education studies. This theory is based on three core variables: dialogue, structure, and autonomy. However, previous research suggests that these variables may function differently in hybrid education compared to traditional distance learning. This review critically examines how these variables apply to hybrid education and identifies potential adaptations needed to make the theory fully applicable in this context. The findings of

this chapter provide a theoretical lens through which to understand the empirical studies in the following chapters, linking observed practices to broader conceptual frameworks.

The fourth and final research question is investigated in **Chapter 5**, which examines an interdisciplinary and international pharmacy course. This study specifically focuses on interaction patterns in hybrid education. Data collection included questionnaires, observations, and interviews, allowing for a comprehensive analysis of how interactions influence student engagement and learning experiences. Additionally, we explored the role of TD in understanding these interaction patterns, examining whether it could help explain differences in engagement between online and onsite students. The study also focusses on the significance of informal interactions, aiming to capture how these less structured exchanges unfold within the broader interaction patterns. By considering these informal aspects of hybrid learning, this chapter emphasizes the importance of social presence and community-building in fostering meaningful engagement across different learning spaces.

Finally, **Chapter 6** presents the general discussion, offering a comprehensive, bird's-eye view of the main findings across all studies. In this chapter, we revisit the overarching goal of the dissertation and show how the results from the four empirical papers collectively advance our understanding of hybrid education. Key conclusions are drawn and related back to the existing literature, highlighting where the findings confirm prior knowledge and where they extend or challenge current theories and practices. Additionally, the chapter critically discusses the strengths and limitations of the combined studies, considering both methodological choices and the scope of the research. Beyond synthesis and evaluation, Chapter 6 also explores the scientific and practical implications of the findings, providing concrete recommendations for educators on how to optimize hybrid teaching practices, enhance interaction, and promote student engagement across online and onsite learning spaces. Finally, the chapter reflects on what these insights mean for the future of hybrid education and research, identifying avenues for further study and potential adaptations of theoretical frameworks such as transactional distance theory.

Taken together, these six chapters contribute not only to the practical understanding of hybrid education but also to the theoretical refinement of transactional distance within this context. By combining empirical evidence with critical analysis, this dissertation illuminates the complexities of hybrid

learning environments, revealing both challenges and opportunities. As such, it serves as a valuable resource for university teachers, instructional designers, and policymakers seeking to design and implement hybrid teaching strategies that enhance learning experiences and outcomes. Moreover, it lays the groundwork for future research aimed at deepening our understanding of the interplay between interaction patterns, engagement, and theoretical frameworks in hybrid education.

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Chapter 1

Chapter 2 University STEM Teachers' Experiences with Hybrid Education during the Covid-19 pandemic

Abstract After the COVID-19 pandemic the use of hybrid formats in higher education and its related questions about interaction, participation, and learning outcomes, have become more prominent. This study explores university teachers' experiences with hybrid STEM education at a large public university in the Netherlands. Our research specifically examines perspectives on technology integration, interaction quality, transactional distance, and attention management within hybrid settings. This qualitative study with nine university teachers utilized semi-structured interviews and both open and axial coding. Findings indicate online interactions were often perceived as less engaging than onsite interactions. Teachers also reported significant challenges balancing attention across online/onsite students, content, and technical demands. Despite difficulties, teachers recognized hybrid education's value for specific scenarios like international collaborations or particular student cohorts. This study illuminates STEM educators' complex realities during hybrid teaching. These insights offer important guidance for targeted professional development and the creation of more effective, equitable hybrid learning environments. The findings address interaction and engagement challenges, enhancing future pedagogical resilience.

Keywords COVID-19, Higher education, Hybrid education, STEM, Teacher experience

Chapter 2

2.1   Introduction

The COVID-19 pandemic necessitated an unprecedented shift in educational delivery worldwide. Educational institutions rapidly transitioned from traditional face-to-face instruction to online and hybrid models, requiring teachers to adapt quickly to new modalities (Adedoyin & Soykan, 2020; Drijvers et al., 2021; Meulenbroeks, 2020; Meulenbroeks et al., 2022). In the two years that followed, teachers frequently switched between fully onsite, fully online, and hybrid formats as lockdowns were imposed, relaxed, or lifted (Barry et al., 2021; Meulenbroeks et al., 2022). They also learned to implement videoconferencing platforms such as Zoom and Teams to maintain instruction and engagement (Adedoyin & Soykan, 2020). This transition was particularly challenging in Science, Technology, Engineering, and Mathematics (STEM) disciplines, where hands-on activities, classroom discussions, and complex problem-solving are integral to the curriculum.

Hybrid education, also known as blended synchronous learning, offers potential benefits such as increased accessibility, flexibility, and reduced student isolation (Grant & Cheon, 2007; Lakhal et al., 2021; Raes et al., 2020). For example, students living far from campus or working full-time alongside their studies can attend lectures online and, in principle, receive equivalent instruction to onsite peers (Q. Wang et al., 2017; Zydney et al., 2018). However, hybrid education also presents challenges, including technical issues, difficulties in fostering meaningful interaction, and the risk that online students feel excluded (Bower et al., 2015; Cunningham, 2014; Szeto & Cheng, 2016). These challenges are particularly pronounced in STEM education, where real-time interaction and immediate feedback are essential for student learning.

Despite a growing interest in hybrid education, few studies have examined its implementation in STEM courses. Previous research has primarily focused on social sciences and teacher education (Bell et al., 2014; Cunningham, 2014; Hall & Villareal, 2015; Lakhal et al., 2021; Raes, 2022; Q. Wang et al., 2017; Zydney et al., 2018). Moreover, research on transactional distance, the psychological and communicative gap between teachers and students (Moore, 2018), in hybrid STEM settings is scarce, especially regarding both teacher-student and student-student interactions.

This study addresses these gaps by exploring how university STEM teachers experienced hybrid education within the contexts of the COVID-19 pandemic. Focusing on STEM courses, which often involve formula manipulation, lab work, and other hands-on activities, allows us to examine

a particularly complex and underexplored educational context. By analyzing interaction patterns and learning experiences, this study provides novel insights into the relational and pedagogical dynamics of hybrid STEM teaching. These insights can inform course design, support teacher practices, and guide institutions in implementing effective hybrid education.

Accordingly, this study seeks to answer the following research question: What were university STEM teachers' experiences with hybrid education during the COVID-19 pandemic?

2.2 Theoretical background

In this section, findings of recent research on hybrid education that inform our study are summarized according to three main themes: (1) Technological aspects, (2) Interaction and transactional distance in a hybrid setting and (3) Teachers' division of attention. Note that many of these studies address the pre-pandemic situation.

2.2.1 Technological challenges of hybrid education

Digital technology necessarily plays a crucial role in hybrid education, and dealing with these technical aspects is found to be one of the biggest challenges within hybrid education (Bower et al., 2015; Lakhal et al., 2021; Raes et al., 2020). Ideally, technology should facilitate comparable educational experiences for all students, whether they participate online or onsite. High-quality two-way audio, for example, enables students to make quick, extensive, and natural remarks and has been shown to enhance the feeling of co-presence (Adedoyin & Soykan, 2020; Barry et al., 2021). However, even when the audio quality is excellent, delays in audio transmission can still occur, making communication cumbersome for online students (Bower et al., 2015).

To ensure smooth interaction, teachers often opt for lower-bandwidth tools such as chat functions instead of higher-bandwidth alternatives like video, since the latter are more prone to interruptions if either party loses their connection (Lidstone & Shield, 2010; Vu & Fadde, 2013). When the audio quality is insufficient or absent, online students are left to interact solely through the chat box. Onsite students, however, report preferring audio over text when communicating with their online peers, as spoken interaction feels more natural to them (Bower et al., 2015; Cunningham, 2014; Zydney et al., 2018). Teachers also face challenges in managing simultaneous communication channels. For instance, some report forgetting to monitor the online chat box, leaving questions unanswered (Wang et al.,

2017). Therefore, multiple studies recommend involving a separate moderator who can represent online students, monitor the chat, and address technical issues, allowing the teacher to focus on instruction (Bower et al., 2015; Cunningham, 2014; Zydney et al., 2018).

All in all, both digital technology itself and the ways it is employed play a major role in hybrid education and strongly influence various aspects of hybrid teaching, notably teacher–student interaction. Given the central role of digital technologies in shaping teachers' experiences with hybrid education, we include this aspect in our coding scheme.

2.2.2 Interaction and transactional distance in hybrid settings

In the quintessential educational triangle, Moore (1989) discerns three types of interaction: student-teacher interaction, student-content interactions and student-student interaction (Moore, 1989; Szeto, 2015; Szeto & Cheng, 2016). Ideally, all three are of a high quality, and especially in distance education it is vital that teachers consciously plan these three types of interactions, (Szeto & Cheng, 2016). Pre-pandemic studies have shown that during a hybrid lesson online students mostly interact with each other and with the teachers, and seldomly with the onsite students (Szeto, 2015; Szeto & Cheng, 2016). Teachers also mentioned that they sometimes found it hard to include online students during group discussions. These teachers suggested that careful planning of the interactions before the lesson improved the number of interactions they had with the online students. However, even in this case, they reported that the online students would ask fewer questions during a lecture than the onsite students (Lakhal et al., 2021). In short, the level of planning of the interaction between the teacher and students can determine the resulting level of participation of the online students. When students do not participate in classroom interaction, this can lead to them not feeling part of the group and experiencing a feeling of distance.

This perceived distance between the teacher and the students affects students' asking questions or participating in group discussions (Lakhal et al., 2021; Moore, 1989, 2018). This perceived distance is called transactional distance. It is the psychological or communicative gap that exists between the teacher and the learner during the transaction that occurs in the structured or planned learning setting (Moore, 2018). The transactional distance between the teacher and the student is influenced by three variables: i) the dialogue that develops between the teacher and the student, ii) the structure of the lesson, and iii) the autonomy of the student (Moore, 2018; Vasiloudis

et al., 2015). All of these variables can influence the interactions the teacher has with the students, and more specifically with the online students (Freeman et al., 2014). As mentioned before, when students experience a higher transactional distance, they most often do not feel part of the class, which may influence their learning engagement and outcomes (Chen, 2023; Kara, 2021). Not only can the interaction that the teachers have with the online students influence the perceived transactional distance, but the technological aspects of hybrid education can also do so. For example, when teachers use higher bandwidth tools, placing high demands on the internet connection, there is a larger chance of losing the connection, limiting the interaction teachers have with their students thus leading to a higher transactional distance (Lidstone & Shield, 2010; Zydney et al., 2018).

All in all, the interaction between the two groups of students and between the student and the teacher can strongly influence the teachers' experiences with hybrid education. Moreover, the possible perceived transactional distance can also influence both the teachers' and students' interactions during hybrid education. Therefore, we have included both the concept of interaction and transactional distance in our analysis.

2.2.3   Teachers' division of attention

During hybrid education, teachers must divide their attention between online and onsite groups. In some cases, onsite students indicated that the teachers paid too much attention to the responses of the online students (Raes, 2022; Szeto & Cheng, 2016). This causes some online students to feel as if they were subjected to greater scrutiny, while the onsite students feel neglected (Bower et al., 2015; Szeto, 2015). On the other hand, some teachers adopted a slower pace with much repetition, negatively impacting the class experience for onsite students (Bower et al., 2015; Szeto & Cheng, 2016). In other studies, teachers found it more difficult to pay attention to the online students, and would sometimes forget they were even there (Lakhal et al., 2021; Q. Wang et al., 2017). The potential lower levels of engagement for either group of students (online/onsite) were reported to lead to lower learning outcomes for that group (Q. Wang et al., 2017).

Lakhal et al. (2021) offer some advice in this area. Firstly, and even more so than in onsite education, course sessions should be planned and this planning needs to be followed. These interactions and possible collaborations may not occur spontaneously (Lakhal et al., 2021). Studies have highlighted that hybrid education demands more physical and social preparation than traditional onsite education (Bower et al., 2015; Zydney et al., 2018).

Secondly, employing a teaching assistant for the technical aspects has been reported to be beneficial (Lakhal et al., 2021). Not only does a teaching assistant help with technical difficulties, but they can also help with the distribution of attention and ensure that online students' questions are answered. Having a teaching assistant managing the chat and technology ensures that the teachers can primarily focus on the teaching aspect of the lesson, and positively affect both the teacher's and the student's experience with hybrid education.

Issues like video and audio quality, connectivity, and teachers' IT skills can significantly impact the student's learning experience. Moreover, these challenges also affect other aspects of teaching, such as balancing online and onsite interactions, dividing attention between both groups of students, keeping both groups of students engaged, and juggling multiple teacher roles.

2.3   Methods

To answer our qualitative research question on the experiences of university teachers' experiences with hybrid education during the COVID-19 pandemic, a semi-structured interview study was adopted (Almeida et al., 2017; Sandelowski, 2000; Smith, 2008)

2.3.1   Participants and context

This study was conducted among STEM teachers at a university in the Netherlands. During the COVID-19 pandemic (2020–2022), these teachers had to rapidly shift to emergency remote teaching. In the Netherlands, several lockdown periods of varying severity occurred: some required universities to close completely, while others allowed a maximum of 75 students onsite in lecture halls, thus enabling hybrid education. Between November 2021 and February 2022, the full complement of STEM teachers at this university who had taught first-year bachelor courses with more than 75 students in the first semester of 2020 or 2021 (N = 24) were invited via e-mail to participate. These first-year courses were selected because they are typically the largest courses at the university and therefore most likely to require hybrid delivery. Out of this sample, nine teachers who had actively used hybrid education agreed to participate in semi-structured interviews. The other teachers either indicated that they had preferred to adopt fully online teaching instead of hybrid teaching, or did not volunteer to participate due to time constraints.

Table 2.1 gives the demographic data of the nine participants. These teachers had been active in three distinct hybrid educational approaches: lectures, project-based learning, and working groups. In lectures, communication was primarily one-way, although teachers encouraged questions to foster a more dynamic learning environment. In contrast, both project-based learning and working groups relied heavily on student–student interaction, which can be more challenging in a hybrid setting. In these contexts, the teacher's role was to guide students, answer their questions, and support their reasoning processes. Importantly, none of the teachers reported to have prior experience with hybrid teaching, however, they all had gained some experience with fully online teaching during earlier lockdowns.

Table 2.1 *Demographic details of the study sample*

Teacher (pseudonym)	Field	Gender	Higher education experience	Teaching format
Adam	Mathematics	Male	>15 years	Lecture
Betty	Pharmacology	Female	> 15 years	Project based learning
Connor	Biology	Male	< 5 years	Lecture
David	Biology	Male	> 15 years	Lecture
Eva	Biology	Female	<5 year	Working groups
Farah	Pharmacology	Female	6-15 years	Lecture
George	Physics	Male	> 15 years	Lecture and working groups
Harry	Mathematics	Male	> 15 years	Lecture and working groups
Irene	Pharmacology	Female	6-15 years	Working groups

2.3.2 Interview protocol

Due to the COVID-19 restrictions in place (there was a lockdown in the Netherlands from November 2021 until February 2022), some of the interviews were onsite, while others were conducted via a videoconferencing platform (Microsoft Teams Classic 2021). These questions are based on results found in Lakhal et al. (2021) and on conversations with teachers who had previous experience with hybrid education. The questions of the interview protocol were deliberately phrased to invite teachers to include any experience, theme or subject they deemed relevant. Moreover, the teachers were specifically asked what they changed in their teaching to adapt to a hybrid setting, inviting them to reflect on their conscious decisions on this subject. Teachers were also asked what they would do differently if they

had to do it again, as well as what they took away from this teaching experience, inviting them to reflect on possibilities to improve hybrid teaching (Appendix A).

Before the interview started, teachers were given a summary of the study and were asked to give their verbal informed consent on the recording. Note that we made a conscious decision not to include questions explicitly pertaining to STEM education. In doing so, we aimed to avoid priming the interviews. It was expected that the sample consisting exclusively of STEM teachers would be sufficient to make the results applicable for STEM education. Our reasoning was: these STEM teachers can only reflect on their own experiences, they are not experts on what is, and what is not, STEM-specific about their teaching. In short: we aimed to make the interview as explorative as possible for the case of science education, while limiting the sample to a specific group. On average, these interviews were about 40 minutes long, with the shortest interview lasting 30 minutes and the longest 50 minutes. In total, 5 and a half hours of interviews were recorded. All interviews were conducted in Dutch, quotes used in this article have been translated into English by a bilingual native Dutch and English speaker.

2.3.2 Data analysis

Table 2.2 Overview of Data Analysis Steps

Step	Description
Transcription	Audio-recorded interviews were transcribed verbatim
Identification	Self-contained quotes relevant to the research questions were identified
Codebook development	Codes were developed using a combination of literature-derived (top-down) codes and bottom-up codes from the data (see Appendix B and Table 3)
Coding of quotes	All quotes were coded according to the codebook; affective qualifiers (positive, neutral, negative) were added for selected categories
Reliability check	A second coder independently coded 20% of quotes; interrater reliability was assessed (Cohen's κ = 0.94)
Qualitative description	Codes were used to generate descriptive insights into teacher experiences
Vignette construction	Two illustrative vignettes were created to contextualize the quotes within typical teaching scenarios

The semi-structured interviews lasted between 30 and 50 minutes and were audio-recorded. After verbatim transcription, each participant was assigned a pseudonym (Table 2.2), starting with a letter in alphabetical order

according to the chronology of the interviews, determined by the participant's availability. The full names were chosen by the researcher to match the participant's gender, making sure that they bore no relation to real names or other identifying characteristics. This procedure follows ethical guidelines for confidentiality. The interviews were then coded in NVivo using a "top meets bottom" approach, which combines both top-down and bottom-up coding strategies (Glaser & Strauss, 2017; Thorne, 2000). In this approach, the four codes that emerged from the literature and four codes emerged from the coding process (Table 2.3). Additionally, five of these categories, Technical aspects, Perceived learning outcomes, Other, Quality of interaction, and Teachers' division of attention, were subdivided by adding a qualification of affective character to the corresponding quotes: negative, neutral, or positive. For example: "I found working with the computer's hard" would be categorized as "technical aspects - negative". By including the affective aspect, we create an impression of the overall experience. Moreover, the categorization of negative, neutral, and positive can also be used to differentiate between possible "good practices" and possible hurdles in hybrid education. The full code book is given in Appendix B. Each self-contained quote was only coded once. Second coding was done on 20% of a total of 144 quotes. Cohen's kappa was found to be 0.94, indicating near-perfect interrater reliability. After analyzing the quotes, we constructed two vignettes to illustrate the range of experiences among the interviewed teachers. One vignette describes teaching in a hybrid classroom, while the other reflects a more traditional classroom setting with a laptop connected to a Teams meeting. The vignettes serve an illustrative function, providing additional context to the interview quotes and helping to situate them within concrete teaching practices.

Table 2.3 *Types of codes used to code the interviews, subdivided by where the codes came from.*

Literature based codes	Interview codes
Technical aspects	Perceived learning outcomes
Quality of interaction in a hybrid setting	Teachers' suggestions
Teachers' division of attention	Teachers' preference
Transactional distance	Other

2.4   Results

In this section, we first present an overview of the coding results, followed by two vignettes that provide additional context. Finally, each code is discussed in detail, supported by relevant quotations.
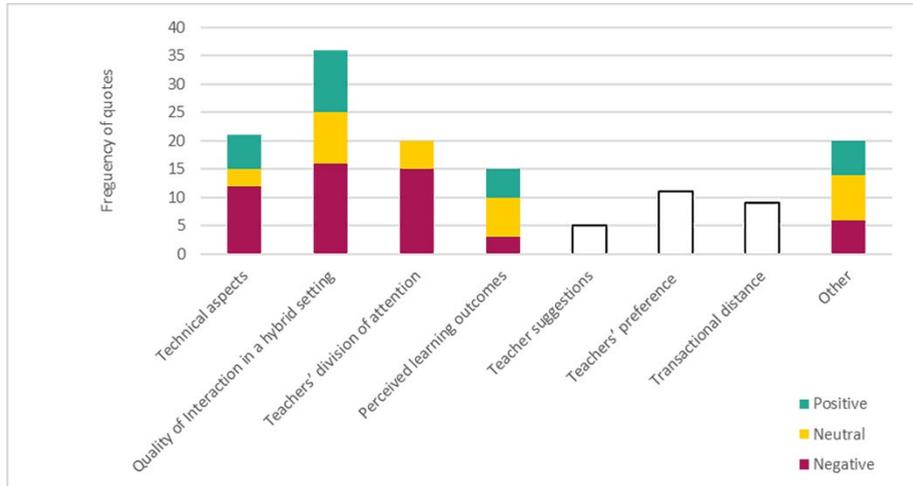
Figure 2.1 *Distribution of the quotes over the eight different categories, in which red shows negative quotes, yellow shows neutral quotes, and green shows positive quotes (N = 144). The white bars indicate quotes that have no affective connotation.*

Figure 2.1 shows the distribution of the quotes over the eight categories. Most quotes (39) fall in the category of "quality of interaction", with eighteen marked as negative, 10 as neutral and 12 as positive. In the rest of the figure, we notice that in three of the five largest categories most quotes are marked as negative. Note that the quotes on student learning outcomes as perceived by these teachers are leaning more towards a neutral or positive stance. To convey an impression of the range of experiences represented by these data, two extreme cases will first be presented in the form of vignettes on hybrid STEM education during the pandemic: one predominantly negative, and one predominantly positive.

2.4.1   Vignettes

The two vignettes are: Adam, a mathematics teacher, whose experiences with hybrid education were largely negative, and Betty, a pharmacology teacher with largely positive experiences with hybrid education during the pandemic.

Adam

Adam is a mathematics teacher who has been teaching at university level for over 15 years. During the COVID-19 pandemic, Adam was required by university regulations to teach one of his bachelor courses in a hybrid manner. He expressed his general impression of hybrid education by stating: "I prefer onsite education and the students do too."

When talking about the technical aspects of hybrid education Adam commented: "What also plays a role, are the technical difficulties. You don't have that when you use a blackboard." Moreover, Adam also expressed strong opinions on the difficulty to keep the balance of attention between his class and the technology: "I can't multitask". He found it very hard to see his students when they were presenting online: "… the screen is really small, I did not know if what I saw was correct, or where the student was in the presentation, which is not a problem normally when they use a blackboard." Adam was under the impression that the students did not enjoy hybrid education, since he felt these first-year undergraduate students, fresh out of secondary education, were not yet ready for this type of education: "They [first year bachelor students] are not independent enough." Adam explicitly refers several times to sorely missing the blackboard in the hybrid environment. In his opinion, this tool is necessary for teaching his subject, mathematics, with its many formula manipulations. Adam illustrates the difficulties that STEM teachers can face during hybrid education, in this case mainly related to the technical aspect, i.e., the absence of a substitute for the blackboard, the attention taken up by the technology, as well as the limited visual quality of the connection. It is not difficult to see why he clearly prefers to teach onsite.

Betty

Betty teaches several pharmacology courses; she has been teaching at university level for over 15 years. During the pandemic, Betty was required to teach hybrid classes, but in contrast to Adam, she had the opportunity to do so in a dedicated hybrid classroom. Her overall impression of hybrid education is strongly influenced by the technical possibilities of this classroom: "I am a fan of the [hybrid classroom]." This hybrid learning classroom is designed to be a hybrid active learning classroom, which can be used in hybrid and onsite sessions. The room has eight large tables, each accommodating six people, with a large screen for viewing. These screens are connected to team breakout rooms, facilitating collaboration. Additionally, there is a sound system above each table, ensuring that online students can hear their onsite group members. Online students are paired together in the

breakout rooms that correspond to the desks of their onsite group members. The online students are displayed on the screen at the table. In the middle of the classroom there is a designated desk for the teacher. A camera streams the teacher's actions to the online students, in case the lesson calls for plenary actions.

Betty felt more included and involved when teaching in the hybrid classroom compared to hybrid education in a regular classroom: "[In a regular classroom] I did not feel included, while in the [hybrid classroom] I felt part of the group." This feeling of being a part of the group gave her the opportunity to move beyond screen interactions and to give her the feeling she interacted directly with the students. When comparing the learning outcomes of hybrid education and onsite education, she stated: "The end result is the same, the same goes for the learning process: it was the same [as in onsite education]." Betty stated that, just like Adam, she found it difficult to divide her attention between the technology and the students when teaching hybrid in a regular classroom. This did, however, change when using the dedicated hybrid classroom: "I was part of the group……. due to the big screens the students really participated and interacted more." She said: "I would recommend everybody to teach in the hybrid classroom." The big difference in their experience between Betty and Adam clearly lies in the quality of the room and the equipment. Note that Betty did not refer to missing a blackboard, but pharmacology relies less on formula manipulation than mathematics.

2.4.2   Category results

Technical aspects

In total, 21 quotes are coded as technical aspects, of which 12 are coded as negative, three as neutral, and six as positive. Most teachers mentioned not being able to see the online students. Furthermore, they found it difficult when there were delays in the sound or video. Moreover, some teachers indicated that software such as MS Teams and Screencopy did not always work properly, resulting in online students not being able to participate or getting low-quality videos. Adam was explicitly negative about the technological aspect of hybrid education, and five out of the twelve quotes that were coded as negative resulted from the interview with him.

> *"But, if you record yourself……in practice, the quality is always bad." –*
> *Adam*

Nevertheless, some teachers did not find the technological aspect difficult. Some of them mentioned that they had extensively used online platforms before the pandemic, and thus were comfortable with them. One teacher mentioned that working in a hybrid setting made them more comfortable with technology.

> *"…the technical support and all the other technical aspects went well…. I'm quite comfortable with doing things digitally…" – Connor.*

Teachers implicated that good audio and video quality made the online students feel more included. Moreover, being able to hear the online students made them feel more connected to the online students. This played a large role in their reported experiences. As we have seen, Betty taught in a classroom specifically designed for hybrid education and was very enthusiastic about the technological possibilities.

Quality of interaction in a hybrid setting

When talking about the quality of interaction the teachers referred to their experiences with teacher-student or student-student interaction. In total, there were 39 quotes regarding the quality of interaction (18 quotes negative, 10 neutral, and 12 positive). Eight out of the nine teachers had at least one negative remark about the quality of interaction in a hybrid setting. Teachers mentioned that they did not feel a part of the group and that it was harder to connect with the students online. Moreover, teachers also thought that the online students were less inclined to ask questions compared to the onsite students.

> *"I did not have a lot of interaction with the people online." – Adam*

> *"What I found hard was to ensure that the people online were involved and participated in the discussion. "– Eva*

Seven of the nine teachers commented neutrally on this aspect and stated that the interaction with the onsite students was the same and that hybrid education was an improvement to fully online education. They also mentioned that the online students were happy that hybrid teaching enabled them to participate in the classes since not all students were allowed to be in the lecture hall.

> *"The students were very happy that they could still participate in their education. Even though they did notice that participating in big group*

discussions was a bit harder [when they participated from home]." – Irene

Four out of the nine teachers explicitly made positive comments about the quality of interaction. Quotes in this category were from two teachers, one of which was Betty, and another who felt that as a teacher they were more approachable to the students due to hybrid education as compared to fully online education. They had positive experiences with using student assistants as moderators, and they mentioned having students who were very engaged.

Teachers' division of attention

In total, there were 21 quotes in the category, Teacher attention online versus onsite, of which 15 were negative, five neutral, and one positive. Five of the nine teachers commented negatively about the division of attention. Most of these teachers mentioned that they found it hard to focus on both groups of students and sometimes forgot the online students were even there. Moreover, they had trouble checking the online chat while teaching.

"Personally, I think that dividing your attention is the hardest part, because I'm mostly focused on speaking to the people in the lecture hall, and then neglecting the people at home." – Farah

Four of the nine teachers had neutral remarks about their division of attention. These teachers were either supported by a moderator or had multiple devices which made it easier.

"I had most of my contact with the students online via chat. For every lecture, I found a volunteer [student] who would monitor the chat for questions, and that kind of worked." – Adam

The results indicate that division of attention might be one of the hardest aspects of hybrid education. Only one teacher, Betty, did not struggle with the aspect. She mentioned that it was not hard to divide her attention, as the online students were projected on a big screen at every table, thus ensuring that they could speak with the online students easily, and be very interactive. Teachers who reported on their experiences in a neutral manner either had a moderator or had multiple devices.

Students' learning outcomes as perceived by the teachers

When talking about the perceived learning outcomes, teachers mentioned how they perceived the students' understanding the concepts, how students asked questions, and what test results they had. In total, there were fifteen quotes about perceived learning outcomes, with three of these quotes coded as negative, seven as neutral, and five as positive. All negative quotes mentioned poorer conceptual understanding, indicating that conceptual understanding developed better for the onsite students than for the online students.

> *"What the [online students] took from it is extremely poor. I think because you don't have the same […] focus, when you're behind a screen." – Harry*

However, most teachers talked about the perceived learning outcomes in a neutral manner, meaning that they thought both the learning process, the depth of the content, and the test results were the same as when they gave their courses in a fully onsite setting.

> *"I think that, in the end, the results—so the product and the learning process—were the same [comparing hybrid education to fully onsite education]." – Betty*

Three teachers were positive about perceived learning outcomes, mentioning that onsite students sometimes stayed in the class after the lecture to further discuss the subject. According to some, teaching in a hybrid manner gave more depth, and improved the learning process, at least when compared to fully online education. According to these teachers, this was a consequence of easier interaction, and they could still see some students onsite. One teacher had the impression that students obtained better results from hybrid teaching than from fully onsite teaching.

> *"I had comparable results, sometimes even higher [when comparing hybrid education to fully onsite education], so similar to better results." – George*

These results show teachers experienced the perceived learning outcomes differently. All of them, however, indicated that they did keep course level and content identical to an onsite version of the course.

Teacher suggestions

Three of the nine teachers had suggestions on how to improve hybrid education. One did not see many advantages of hybrid education compared to online and onsite education but did indicate it could be useful for international or nationwide courses. To be able to focus more on the actual interaction, the use of a moderator was suggested. Moreover, a teacher also suggested that she would want to prepare more, so she could create a more interactive lesson. Another suggestion concerned a student buddy system in working groups to ensure students would alternate between online and onsite attendance within the same hybrid course.

> *"So, if you really want to work in a hybrid setting and want the people at home to participate interactively, you really need a second teacher or a student assistant. Because then you help the students at home to participate."- Eva*

In summary, only a few teachers provided suggestions for improvement, but those who did emphasized the need for more preparation, additional support during classes, and structural solutions to ensure equal participation of online and onsite students.

Teachers' preference

When talking about their preferences, teachers mentioned whether they preferred fully onsite, fully online, or hybrid education. Most teachers preferred fully onsite education to both online and hybrid education. However, when comparing hybrid education to fully online education, most teachers preferred hybrid education, as there was more interaction in a hybrid setting. However, there was one teacher who preferred online education over fully onsite education when it came to their lectures, as according to them these lectures were not meant for interaction. Conversely, a teacher stated that there was barely any difference between hybrid and fully onsite education if most of the students were present in the classroom.

> *"Hybrid is better than online, and hybrid is almost as good as on location." – Harry*

Overall, teachers' preferences showed a clear tendency toward onsite education, with hybrid education generally seen as the better alternative when compared to fully online formats.

Transactional distance

In total, 5 teachers described situations that are related to the concept of transactional distance. They mostly described the feeling of not being a part of the group and feeling a bigger distance between themselves and the online students compared to the onsite students. This feeling of a greater distance made them doubt whether the online students, especially first-year students, were comfortable asking questions (thus limiting the possibilities for dialogue) and wondered if this also impacted their learning engagement.

> *"I enjoy talking to a screen less because then there is a certain distance and I feel like certain things are not getting communicated how I would like." – Eva*

> *"What you see is that the online students are less present during group discussions. It's because they are not really a part of the group not in the context of the classroom, so I think it would make them dropout faster."*
> *– Farah*

In summary, teachers experienced a greater sense of distance toward online students, raising concerns about reduced dialogue, participation, and engagement compared to onsite students.

Other

Quotes that did not fall in any of the other categories and could not be clustered were put in this category. In total, there are 24 quotes of which nine are negative, eight are neutral and seven are positive. Teachers mentioned that freshman students are not independent enough for hybrid education and get too easily distracted. They also mentioned that sometimes nobody showed up to their onsite lectures and thus they went fully online again:

> *"Especially, since the university emphasized how important it is for the students to come back to campus and to meet and interact with each other. Then you organize a whole lecture, which takes quite some effort, and then they don't show up. I think that is very disappointing, especially when you have guest speakers who came to campus for this." – Irene*

> *"Many students [online students] told me that it's harder to keep their focus on the lesson because they get distracted at home, and then it's hard to regain their focus." - Harry*

Teachers also mentioned that hybrid education was a fine solution for emergency education and that it was "better than nothing". Moreover, other neutral remarks were that it was a good option for students who had to stay at home, while the "healthy students" could go to campus. However, most teachers would not recommend hybrid education for first-year bachelor's students, considering them not yet mature and independent enough and referring to the importance of getting to know their fellow students.

> *"Yes, it is better than nothing. If you are in a situation with COVID, and you can't come to university due to the risk, then it is for sure a sensible way to teach." – Adam*

2.5   Discussion and conclusions

This study posed the following research question: What are the experiences of university teachers with hybrid education during the COVID-19 pandemic?

The two vignettes show that there is a big range of experiences within the cohort of teachers from very negative to very positive. The positive experience seems to have been largely due to the availability of a dedicated hybrid classroom. The teachers in our sample, in accordance with previous research, indicate that technology is an important conditional factor (Lakhal et al., 2021; Raes et al., 2020). With low-quality audio and video, e.g., with delays in audio and video delivery or lack of clear voice communication, effective hybrid education is very difficult to attain.

Even with high-quality audio and video, teachers noted that the online students were less inclined to ask questions, leading to the teacher having less interaction with them. All teachers commented on the quality of the interaction. It was difficult for teachers to divide their attention between the two groups of students. Previous research indicated that instructors often struggled to balance their attention, either focusing too much on the online students or not enough. (Bower et al., 2015; Lakhal et al., 2021; Szeto & Cheng, 2016; Wang et al., 2017). Our study partly aligns with these findings, in the sense that most teachers did indeed report not paying enough attention to their online students. This was the case for both lectures and working groups. Teachers reported difficulties in keeping track of the online chat while teaching. They suggested the use of a dedicated moderator, as it allowed them to focus solely on teaching rather than dividing their attention. None of the teachers mentioned paying too much attention to the online students. Teachers also ran into problems regarding the students' attitude and ability. This was found in both the categories "perceived learning

outcomes" and "other". Teachers reported that students at home were easily distracted and did not comprehend the content as well as the onsite students.

Interestingly, and in contrast to the teachers' expectations about the comprehension of online students, final student grades were largely comparable to those of traditional onsite courses, a phenomenon also reported elsewhere before the pandemic (Conklina et al., 2017). Beyond grades, this study sheds light on the less explored relationship between hybrid education and transactional distance. As discussed in the theoretical background, transactional distance theory posits that the perceived psychological and communication gap between teachers and learners is influenced by dialogue and course structure (Moore, 2018). In our study, teachers reported difficulty connecting with online students, whereas interactions with onsite students were perceived to be more fluid. This suggests that teachers experienced different levels of transactional distance with the two groups. This important nuance is often overlooked in the literature, which typically treats all students within hybrid classes as a single group regarding transactional distance (Murray et al., 2021). One teacher who used an active hybrid classroom with high-quality audiovisual equipment reported minimal transactional distance and effortless interaction with both groups, indicating that effective dialogue can substantially reduce perceived distance. Other teachers struggled to divide attention between online and onsite students. Literature suggests that this issue can be mitigated by carefully structuring interactions to ensure engagement across both online and onsite modalities within a hybrid setting (Athens, 2023; Bower et al., 2015; Francisco-Pérez et al., 2023; Lakhal et al., 2021). Interestingly, this suggestion appears to contradict current transactional distance theory, which posits an inverse relationship between structure and dialogue (Moore, 1997). Our findings imply that in hybrid STEM settings, increased structure may be necessary to facilitate dialogue and reduce transactional distance, particularly when managing dual student groups with differing access to the teacher. This highlights a possible highly interesting refinement to transactional distance theory, emphasizing the need to separately consider online and onsite students within hybrid classrooms.

Moreover, our study also provided some insights that were not discussed in literature thus far. Firstly, some teachers proposed that first-year students lack the self-regulation needed to function optimally in hybrid education. They suggested that going to campus is more important for first year students, for them to become accustomed to the university and the

coursework and to have social interactions with other students (Papageorgiou, 2024). These findings are consistent with results in the context of fully online education (Stephen & Rockinson-Szapkiw, 2021). Furthermore, studies in fully onsite education show that student self-efficacy is an important predictor for student engagement in general (Fokkens-Bruinsma et al., 2021). This could explain why first-year bachelors' students might not thrive under either online or hybrid education, as self-efficacy tends to grow with student experience and clearer expectations, aspects that first-year students need to develop (Aguilera-Hermida, 2020; Fokkens-Bruinsma et al., 2021).

Secondly, few quotes specifically addressed the STEM nature of the course, our interview protocol having deliberately avoided priming the discussion. However, there are some interesting remarks regarding mathematics teaching. Both mathematic teachers had a different experience with teaching in a hybrid setting. Adam specifically referred to the absence of a blackboard for formula manipulation in mathematics. This influences his experience, as he found that his students performed better when he did use a blackboard and for him that was an essential part of his teaching; this, however, was not possible in a hybrid setting. Harry did not encounter this problem, as he did not use a blackboard but a tablet to create the same effect in his lectures. The use of his tablet was more adjustable to hybrid education then a blackboard was. In conclusion, these findings contribute to the growing body of knowledge on hybrid education and call for further exploration and consideration in educational practices.

These subject-specific experiences illustrate how hybrid teaching poses different challenges depending on teaching style and discipline, but they also point to a broader discussion about the relevance of hybrid education beyond the immediate pandemic context. The COVID-19 pandemic placed hybrid education firmly on the agenda in higher education, both as an emergency solution and as a catalyst for pedagogical innovation. In our study, the pandemic serves only as the contextual backdrop in which teachers gained their experiences, rather than an explicit variable in our analysis. Yet, evidence from recent research shows that the lessons and practices developed during the pandemic continue to be relevant and are being leveraged to improve hybrid education today. For instance, hybrid teaching is now regarded as a persistent trend in educational reform, with ongoing attention to challenges such as fostering student participation and self-efficacy (Chen et al., 2024), and empirical work demonstrates how factors such as interactivity, social influence, and institutional support

continue to shape student satisfaction in hybrid learning after the pandemic (Sedrakyan et al., 2023; X. Wang et al., 2024). Qualitative studies also indicate that students still perceive both advantages and drawbacks of hybrid environments, many of which are directly linked to experiences during the COVID-19 lockdown (Ma'ruf, 2023), while studies on digital feedback highlight that hybrid formats remain preferred by many learners, provided that feedback, social presence, and motivation are adequately addressed (Sedrakyan et al., 2023). Systematic reviews further confirm that hybrid teaching is not merely a temporary solution but has become an integral part of higher education's pedagogical landscape, supported by technology integration and evolving instructional design (Ottenheim et al., 2025; X. Wang et al., 2024), and research in business schools shows how institutions have deliberately used experiences from emergency remote teaching to transform and strengthen hybrid approaches in the post-pandemic era (Clifft & Assiouras, 2022). Together, these studies suggest that although the immediate emergency caused by COVID-19 has passed, its effects on how hybrid education is designed and evaluated persist; the tools, concerns, and priorities that emerged during that time continue to inform current practice and institutional decision-making. In conclusion, these findings contribute to the growing body of knowledge on hybrid education and underscore the need to further explore how lessons learned during and after the pandemic can inform future educational practices.

2.5.1   Limitations

This small qualitative study adds to the research on hybrid education in the sense that it gives an overview of the varied experiences of higher STEM educators. Firstly, our qualitative methods use semi-structured interviews with STEM teachers. Thus, we only got their perspective on hybrid education. However, in our sample, we do not have any teachers who taught chemistry, computer science or biomedical science. Moreover, teachers in our sample did not perform experiments, ubiquitous in chemistry or physics curricula, in their courses during the pandemic. The teachers in this study do cover a range of different subjects, and are of different gender and experience levels, from novice to very experienced. Moreover, there is also a wide variety of experiences with hybrid education ranging from very negative to very positive and from low-tech to high-tech. Thus, our sample represents a wide variety of tertiary STEM teachers.

As mentioned before, the interview questions are deliberately phrased in a general manner to allow the teachers to express themselves freely, without priming them in a certain direction (Merriam & Tisdell, 2015). One

could argue that this would lead to some STEM-specific challenges being overlooked. However, the sample itself was chosen to delineate the area of STEM teaching. Thus, by default, all the teachers discussed STEM-specific topics, some of them very specifically so, e.g., the use of traditional blackboards in mathematics. Teachers also talked about being able to draw complex figures for their courses on the screens that they used and how the technology sometimes made this harder. We intentionally avoided asking the teachers STEM-specific questions to ensure that we did not impose our own perspective on what constitutes STEM-specific teaching. Additionally, this approach prevented the need for teachers to articulate distinctions between STEM teaching and teaching in other subject areas, which may not align with their expertise or focus

2.5.2   Recommendations for educational practice

We hypothesize that transactional distance contributes to the various challenges faced by the teachers in this study. To address this, we propose the following strategies to reduce the perceived distance. Teachers mentioned that they did not feel as if the online students were part of the classroom, making it more difficult to interact with them and sometimes leading to the teacher not paying attention to those students. Therefore, teachers could plan their interactions with the online students, so they do not forget them and increase the existing dialogue with these students. According to the literature and one of our teachers, this should lead to them feeling like they are part of the classroom. Moreover, employing a moderator dedicated specifically to supporting online students could assist teachers in effectively managing their division of attention. For instance, this moderator role could rotate among the students, with a different student taking on the responsibility in each lecture. Having a moderator would ensure that the online students would not be neglected; however, the original problem of an increased transactional distance would remain, as the moderator would mostly use the chat, which creates little dialogue between students or between students and teachers.

2.5.3   Future studies

Our research adds to the already existing body of research on hybrid education. Interestingly, we have found that our findings on the experiences of STEM teachers are similar to the findings of studies that worked with social science teachers (Lakhal et al., 2021; Raes, 2022), with some notable exceptions. Addressing the students' experiences of hybrid education might contribute to identifying the benefits and pitfalls of hybrid education. Their perspective would specifically be interesting if the students have

experienced both the online and onsite side of hybrid education. The concept of transactional distance can serve as a valuable guiding framework for designing future studies. Moreover, a design study on the scientific discourse conducted in hybrid STEM courses would also contribute to existing knowledge in this field, as one could experiment with different factors (e.g., moderators, active learning techniques) to improve the hybrid education experience in a realistic setting. This would not only be beneficial in future crises, but also improve the educational experiences of future students and teachers.

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Appendices

Appendix A: Interview Protocol

The following guiding questions were asked:

1. What is your experience with hybrid education?
2. What did you find hard about hybrid education and what went well?
3. Which activities/ teaching methods did you use during your lessons?
4. What did you change and what did you keep the same with respect to normal/onsite teaching?
5. Did teaching in a hybrid manner result in the same depth (meaning the course level and content) as your normal onsite or online teaching?
6. What did you learn from teaching this (hybrid) way?
7. If you had to do it again, what would you change?

Appendix B: Codebook

Table 2.3 Codebook, describing eight coding categories and showing examples for each of them. The categories are divided into Negative (-), Neutral (0) and Positive (+). After each example it is shown whether it is considered negative, neutral or positive.

Category	Description	Example
Technical aspects	Statements explicitly referring to the use of technology in hybrid settings and to teachers' earlier experiences with IT.	What went well was the technical support and all the technical things just went really well. I am however very comfortable with fixing everything online and all the systems, so that goes really well. (+)
Quality of interaction in hybrid settings	Statements regarding teacher-students and student-student interaction.	In principle its fine, I do have the idea that there was less interaction from the students online than those in the lecture hall. (-)
Teachers' division of attention	Statements regarding the division of teachers' attention between the online and onsite students	But you do notice that when you really teach in hybrid education that you eventually will focus on the students in the lecture hall. That is the only ambiguous thing about it. (-)
Perceived learning outcomes	Statements regarding the teachers' perception of student subject understanding in a hybrid setting.	I am wondering how much the online students understood/take away. (-)

Category	Description	Example
Teaching Load	Statements regarding the reported amount of effort required for teaching in a hybrid setting	You got two different education concepts that you have two uses at the same time and that is hard. (-)
Teacher suggestions	Teachers' suggestions for improvement and application of hybrid education	For example, in international courses that I and [name of a teacher] give. For this it is very practical when on both locations people can sit together and still communicate with each other. That is where I see an advantage. (+)
Teacher preference for onsite, online or hybrid education	Statements regarding the teachers' preferences for hybrid, online or onsite education	Yes, hybrid had my preference. I found it hard to see where the online students are and if they have already got distracted. (+)
Other	Statement related to hybrid education that do not fall in one of the other categories	So, I even when I did it "cobbled-together", I had a good experience. (+)
Transactional distance	Statements regarding a perceived distance between the teacher and the student, a sense of belonging. This also includes the aspect of group feeling and being a part of a group	I enjoy talking to a screen less, because then there is a certain distance and I feel like certain things are not getting communicated how I would like.

Chapter 3 Transactional distance and interaction in hybrid education; A case study

Abstract In recent years, hybrid education received increasing attention from researchers, focusing on the aspects of teaching and interacting with two separate groups at the same time. Teachers and students both struggle with interaction with online students. We hypothesize that transactional distance might play a role in this. This study, therefore, aims to identify and describe the characteristics of hybrid education in terms of interaction and transactional distance. In this case study, we observed four hybrid lectures of a university course on the history of physics course. After each lecture, the students (N=6) received a survey assessing transactional distance; after all four lectures, students and teachers participated in individual semi-structured interviews. Our findings indicate that online students experienced limited engagement in group discussions, mainly asking for clarification when teachers asked questions. Moreover, online students also experienced a greater transactional distance compared to their onsite counterparts. This disparity in engagement and perceived distance may stem from the online students' inability to partake in the informal interactions occurring before, during, and after the lectures. Both students and teachers stressed the importance of this small talk when talking about the differences between online and onsite students. In conclusion, our research underscores the essential role of informal interactions in hybrid education, emphasizing the need for deliberate efforts to facilitate such exchanges for building a cohesive classroom community and enhancing student engagement and learning outcomes.

Chapter 3

3.1   Introduction

Hybrid education, with synchronous onsite and online instruction, has received considerable attention since the pandemic (Raes et al., 2020). However, the concept has been used for decades, e.g., in areas where students have long travel times (Lakhal et al., 2021; Raes, 2022; Szeto, 2015; Wang et al., 2017) or when students juggle multiple responsibilities, balancing work commitments with their academic pursuits, or have to deal with health challenges. By offering synchronous learning opportunities, hybrid education accommodates the diverse needs of students (Lakhal et al., 2021; Raes et al., 2020). Moreover, it also provides opportunities for collaboration between institutions that are separated by large distances (Lakhal et al., 2021; Raes, 2022; Wang et al., 2017).

Catering to both online and onsite students within one lesson is not without its challenges (Lakhal et al., 2021; Raes, 2022). For example, in hybrid education, video/audio quality and continuity are crucial (Kassandrinou et al., 2014). Moreover, online students have been reported to ask fewer questions compared to their onsite counterparts (Kassandrinou et al., 2014). Similarly, teachers found it harder to "read" the online students, since the body language aspect is significantly reduced. Teachers reported focusing on the onsite students, neglecting the learning process of the online students. In education, the interaction between students and teachers plays an essential role in the learning process (Freeman et al., 2014; Moore, 2018). The ability to ask the teacher questions and discuss content with fellow students is often crucial in the learning process (Freeman et al., 2014). Additionally, interaction allows students to see different perspectives and challenge their assumptions. This kind of interaction is needed to gain new insights and develop a more comprehensive understanding (Kim et al., 2013).

Interaction, however, is a challenging aspect of hybrid education (Bower et al., 2015; Lakhal et al., 2021; Raes, 2022; Szeto & Cheng, 2016), especially for the online students. A key concept in interactions and dialogue is transactional distance, defined as the perceived distance between the students and their teacher and having three components, dialogue, structure, and autonomy (Moore, 2018). Various studies have explored transactional distance across different learning environments (Bond et al., 2020; Cahapay, 2020; Gray & DiLoreto, n.d.; Joksimovic et al., 2015; Kara, 2021; Kassandrinou et al., 2014; Lowenthal & Dunlap, 2018; Martin et al., 2019; Martin & Bolliger, 2018; Moreno et al., n.d., n.d.; Murray et al., 2021; Paul et al., 2015; Vasiloudis et al., 2015; Zhang, 2003). In fully online education, transactional distance tends to be higher than in fully onsite

education (Murray et al., 2021). This negatively impacts interactions, dialogue and the overall learning experience. Studies show that fostering dialogue and meaningful interactions remains one of the biggest challenges of online education (Gray & DiLoreto, n.d.; Kara, 2021). Key factors contributing to this challenge include teacher presence and student engagement. Multiple studies have demonstrated that increasing dialogue, and thus also student engagement, and fostering a sense of community can decrease the perceived transactional distance (Joksimovic et al., 2015; Lowenthal & Dunlap, 2018; Martin et al., 2019; Martin & Bolliger, 2018). For example, Martin and Bolliger (2018) found that engagement strategies such as increasing dialogue with interactive discussions increase student involvement and interactions, thereby lowering the transactional distance (Martin & Bolliger, 2018). Similarly, Lowenthal and Dunlap found that leveraging social media and online communication tools created a sense of presence which made both students and teachers feel more connected, which helped reduce the transactional distance (Lowenthal & Dunlap, 2018).

Remarkably, transactional distance has not been extensively studied in hybrid education. There have been comparisons between online, hybrid, and onsite education but not in hybrid education specifically (Kara, 2021; Murray et al., 2021; Vasiloudis et al., 2015). Murray et al. *(2021)* specifically addressed the differences in transactional distance between the three types of education. However, in this particular study (Murray et al., 2021), the hybrid group is seen as one group instead of the two groups that are present in hybrid education. This thus does not show whether and how transactional distance impacts both groups of students during hybrid education. Moreover, in some studies, the concept of transactional distance is stressed as an important aspect of hybrid education; however, the theory is then not used in the methods of the study (Bower et al., 2015; Conklina et al., 2017; Nussli & Oh, 2024; Roberts et al., 2024). This shows that the theory of transactional distance is thought of as important in hybrid education, but is not thoroughly studied in this context. Therefore, we are left to wonder how transactional distance influences classroom interactions and participants' experiences. On the basis of the existing literature, we hypothesize that a large transactional distance plays a big part in the challenges of hybrid education, especially for online students, as they have a harder time participating in classroom interaction.

As a first step towards overcoming difficulties with interaction in hybrid education, this paper aims to identify the possible limitations of hybrid

education when it comes to interaction and transactional distance and to offer suggestions for means to deal with these limitations.

3.2   Theoretical framework

To address the issue at stake, the study's theoretical framework includes notions of transactional distance and interaction within the context of hybrid education. Before elaborating on these notions, we first sketch a brief history of hybrid and distance education.

3.2.1   History of hybrid and distance education

When we use the term hybrid education, we refer specifically to an educational approach which includes synchronous onsite and online meetings. Hybrid education thus caters to two groups of students, online and onsite, instead of having all students either online or onsite. In contrast, online education refers to a situation where all students are present in an online environment, whereas distance education refers to a situation where students and teachers are separated by distance, which may or may not involve online components.

Hybrid and online education have become widespread due to social distancing policies adopted during the pandemic. However, many forms of distance education, known as correspondence studies, have been around for over a century (Pittman, 1991). Radio and television allowed distance educators to go beyond text-only material (Simonson et al., 2011). In 1970, Stanford University implemented a form of hybrid teaching, broadcasting lectures given in one hall to screens in other lecture halls (Pettit & Grace, 1970). After 1990, multiple open universities used distance education platforms (mail, television, taped recordings) to make higher education more accessible to the public. After the advent of the internet, in 1998 the first web-based, online instruction was launched. The concept of hybrid education as we understand it today emerged around 2009. For example, Lakhal and colleagues used hybrid education to provide education both for the students who lived close to campus and students who lived too far away from campus to commute. Their study has also implied that interaction is something that might be harder to achieve in a hybrid setting but with some extra preparation is possible (Lakhal et al., 2021).

3.2.2   Transactional distance

The concept of transactional distance was first introduced in 1997 in relation to distance education (Moore, 2018). Transactional distance refers to the psychological and emotional distance between the teachers and the students

and between the students themselves (Moore, 2018). Transaction refers to the exchange of ideas, experiences and other types of knowledge between the teacher and the students and/or between the students themselves (Moore, 2018; Zhang, 2003). The concept of "distance" in transactional distance refers to the perceived barriers (physical, emotional, psychological) during these interactions or transactions. A higher transactional distance refers to higher perceived barriers.

Transactional distance is based on three variables: dialogue, structure, and autonomy (Figure 3.1). Moore starts by suggesting that more dialogue will lower the transactional distance. Secondly, more preparation by the teacher will increase the transactional distance, due to the less spontaneous interaction and dialogue. Autonomy refers to the amount of work a student needs to do independently of other students and the teacher. In a lesson with plenty of dialogue, a student thus needs less autonomy than in a lecture without dialogue. This implies that students who prefer to work more autonomously could perform better in a setting with a higher transactional distance than less autonomous students.

| Dialogue | Transactional distance | Structure | Transactional distance | Autonomy | Transactional distance |
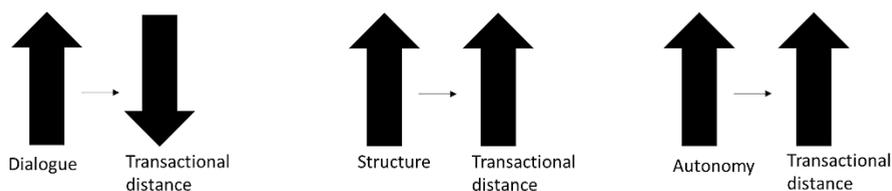
Figure 3.1 *Summary of how the three variables: dialogue, structure and autonomy affect the transactional distance. E.g., more dialogue results in a lower transactional distance.*

Murray et al. (2021) measured the transactional distance in online, hybrid and onsite lessons and found that the students in the online lessons perceived the highest transactional distance, followed by the students in the hybrid lessons, with the onsite students scoring lowest. In hybrid education, differences in engagement, interaction and communication between online students, onsite students and the teacher can lead to a higher transactional distance (Moore, 2018; Vasiloudis et al., 2015). However, this study does not differentiate between the online and onsite students in the hybrid setting. Online students in a hybrid setting often report feeling a lack of presence and little to no interaction with their onsite counterparts and teacher (Lakhal et al., 2021; Wang et al., 2017). These differences in engagement, interaction, and thus dialogue, can lead to a higher transactional distance for online

students. This could result in unequal learning opportunities, negatively impacting online students.

The concept of transactional distance is central to educational interactions, and we hypothesize that it is at least as important within the context of distance and hybrid education, given the physical separations involved. For our study, we explore the different aspects of transactional distance, specifically the student-teacher and student-student interactions. We will measure this perceived distance with the Zhang scale of transactional distance (Zhang, 2003), with four dimensions: the transactional distance between students, the transactional distance between the student and the teacher, the transactional distance between the student and the content and the transactional distance between the student and interface (online course management system).

3.2.3   Interaction in hybrid educational settings

Interaction can be defined as communication between the teachers and the students. This does not only include verbal communication, such as dialogue, but also non-verbal communication, such as body language (Bambaeeroo & Shokrpour, 2017; Howe, 2023). Students who actively participate in classroom discussions show improved communication skills, demonstrate higher motivation, and higher learning gains (Rocca, 2010). According to Moore (1989), there are three types of interaction in a classroom setting, student-teacher interaction (S-T), student-content interactions (S-C) and student-student interaction (S-S) (Moore, 1989). Ideally, all three types of interaction are of high quality, so it is vital that teachers consciously plan these three types of interaction. This becomes even more crucial in distance education since improvisation is more challenging when teachers and students are not in the same location (Szeto & Cheng, 2016).

In S-T interaction, both teachers and students report that the teacher either forgets the online students or is overly focused on those online students. The latter makes online students feel as if they are under scrutiny and makes onsite students feel forgotten (Lakhal et al., 2021; Wang et al., 2017). Moreover, online students are more likely to communicate with their teachers, while onsite students are more likely to interact with each other (Szeto & Cheng, 2016). The S-C interaction does not necessarily suffer for the online group, e.g., because the material is available online. However, both mathematics and physics teachers tend to use black- or whiteboards to manipulate formulas. This board is visible for a student in the classroom; however, this may not be the case for the online students (authors, 2024),

making it harder for them to follow the lecture. Turning to S-S interactions, hybrid education has two groups of students (online and onsite). These groups interact with each other, but they can also interact within their group (Szeto, 2015; Szeto & Cheng, 2016). Hybrid education can thus influence S-S interaction by limiting the interaction between the online and onsite students and creating an environment in which most of the interactions are within the groups. These findings suggest that in hybrid education one needs to extend the three types of interaction. This was also suggested by Szeto & Cheng (2016), who implied that for every category there was a direction of interaction and that the category instructor-content should be included (Szeto & Cheng, 2016).
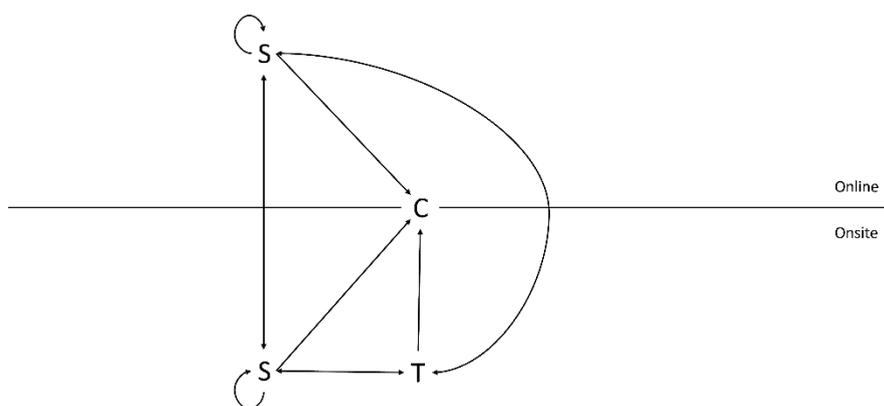
Figure 3.2 *Guiding framework designed to represent the different types of interaction that can take place in a hybrid lesson. C stands for content, S stands for students and T for teacher.*

We extended this model (Szeto & Cheng, 2016), based on the literature and our previous research, to create a guiding framework for interaction within hybrid education (Figure 3.2). The framework assumes that the teacher is present onsite. We will not include the direction of the interaction in our framework for simplicity. The adjusted framework includes the following types of interaction: student online – student online (SoL-SoS), student online – teacher (SoL-T), student online – student onsite (Sol-Sol), student online – content (SoL-C), student onsite – student onsite (SoS-SoS), student onsite – teacher (SoS-T), student onsite – content (SoS-C) and teacher – content (T-C) (Figure 3.2). In the model, content is placed between the online and onsite dimensions, as the content itself is not specific to either the online or onsite students. Both groups of students will see the same (digital) content, such as a presentation, whether they are online or onsite. For this study, we will focus on the interactions in a hybrid lecture, specifically on the

dialogue aspect of interaction. Thus, we not only study how interaction takes place in these types of settings, but also the effect transactional distance can have on this interaction.

3.2.3 Research questions

Using the different elements in the theoretical framework, we phrase the following research questions.
1. How does student-student and student-teacher transactional distance develop during a hybrid university course setting?
2. How do online and onsite students interact during classroom discussions in a hybrid university course setting?
3. What do students and teachers report about their experiences with the different types of interaction in a hybrid setting?

3.3 Methods

To answer these questions, we will use three different methods, thus making this study a mixed methods study. First, we will make use of a questionnaire to measure the perceived transactional distance (Paul et al., 2015; Zhang, 2003). We will also make use of conversation analysis, specifically turn-taking analysis, to be able to see which interactions are at play during a hybrid lesson (Sacks et al., 1974). And lastly, we will conduct semi-structured interviews to gain insights into the experiences of the teachers and students in this course (Lakhal et al., 2021). This way we can determine whether what we have measured and observed in the classroom matches with how the teachers and students experience the hybrid lessons. Thus, this is also a way to triangulate the data. This triangulation has not been encountered in other studies in similar settings (e.g., Bower et al., 2015; Lakhal et al., 2021; Murray et al., 2021; Raes, 2022).

3.3.1 Context

This study was conducted in the context of a transition program that provides master students with the domain-specific knowledge needed to enter a secondary school physics teacher training program. The course subject is the history of physics, designed to address any lacunae students may have that prevent them from entering a teacher training program. The course consisted of nine 2-hour sessions. The course was taught by two teachers, who have both given this course for several years. Both teachers were present for every lesson, but only one taught the class while the other would manage the online students and jump in with any extra information when needed. Also, both teachers taught this class during COVID-19, so they were familiar with teaching this course fully online and in a hybrid setting. The

students in this course also have experience with both fully online and hybrid courses.

3.3.2 Participants
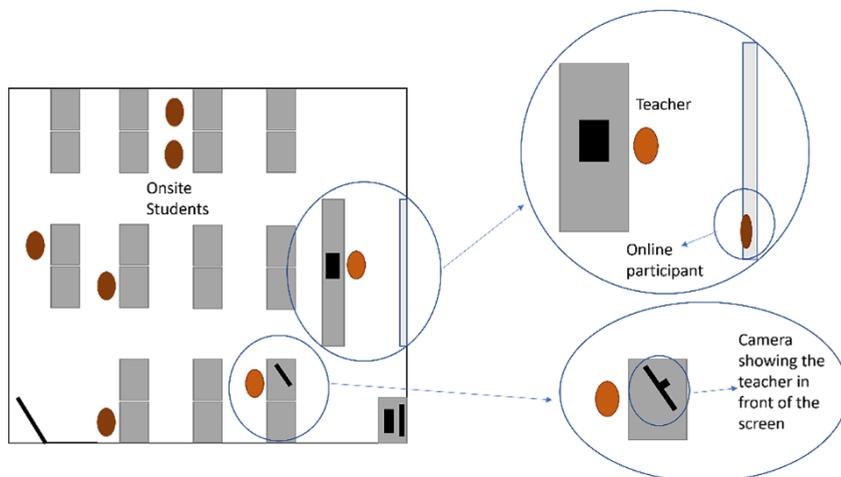
Figure 3.3 Classroom setup. The grey rectangles depict the tables, the brown dots the students and the orange dots the teacher.

Two teachers taught the course to six students. All participants were male and between the ages of twenty and fifty. Two of these students already had teaching experience in a different topic, while the other four did not have any experience as a teacher yet. In five sessions, both teachers were present in the classroom, one teaching and the other monitoring the camera for the online students. Table 3.1 shows the attendance. The teachers used a big screen to project their presentations and used a videoconferencing platform to converse with the online students and share presentations. The camera, speaker, and microphone were integrated into one tablet. In Figure 3.3, the classroom setup is shown schematically. All participants signed informed consent forms for classroom data collection before the start of this study, and separate informed consent was obtained for the post-course interviews.

3.3.3 Instruments

In total, we used three different data collection instruments. We collected the transaction distance questionnaires (RQ1), the conversation analysis data (RQ2), and the interview data (RQ3).

Table 3.1 *Overview of recorded lectures, attendance, and where the students and teachers were present, with the online students shown in bold.*

Lectures						
Who	Lecture 4	Lecture 5	Lecture 6	Lecture 7	Lecture 8	Lecture 9
S1	Onsite	**Online**	Onsite	Onsite	-	Onsite
S2	Onsite	Onsite	Onsite	Onsite	Onsite	Onsite
S3	Onsite	Onsite	**Online**	Onsite	-	-
S4	Onsite	-	**Online**	Onsite	Onsite	Onsite
S5	**Online**	-	Onsite	Onsite	**Online**	Onsite
S6	Onsite	Onsite	Onsite	Onsite	Onsite	Onsite
D1	Onsite	Onsite	Onsite	Onsite	Onsite	Onsite
D2	Onsite	Onsite	Onsite	Onsite	**Online**	Onsite

Transactional distance questionnaire

To answer the first research question, we used a revised version of the Zhang scale. The original Zhang scale was designed for distance education and measures four different constructs related to interaction: student-teacher (S-T), student-content (S-C), student-student (S-S), and student-interface (Zhang, 2003). Since we are specifically interested in the student-teacher and student-student interactions we will only focus on these constructs. Furthermore, we have only included the questions that were relevant to our hybrid education (Appendix A). The revised scale was piloted with a group of students (N=25) without any overlap with the participants. The used scale is based on a Likert scale and consists of ten statements. Cronbach Alphas for both constructs, S-T and S-S, were all above 0.7 in the pilot. During the actual study, the Cronbach Alphas were satisfactory as well (0.775 and 0.8 for the S-T and S-S constructs, respectively). The questionnaire was administered after every lecture. In total, the questionnaire was filled out 38 times, 33 of which were by the onsite students and 5 by the online students.

Conversation analysis

To answer the second research question, we recorded the lessons in this course, which were then used for conversation analysis. In total, there were nine lessons, one of which was in a science museum, which was not included in the data collection. Of the eight lessons left, the first two were used as a pilot (Table 3.1) for this study ensuring that recording devices worked and the classroom setup was optimized. However, students filled out the questionnaire right from the start. To stimulate discussions, the teachers gave the students text to read and assignments to make before the lesson; these texts and assignments were then discussed in depth during the lesson. Thus, the flipped classroom approach is used (Bergmann & Sams, 2012). For example, before a lecture, students were provided with a preparatory text, distributed one week in advance. This text included questions designed to

encourage critical thinking about the topic and its relations to contemporary physics. Students were instructed to read the text and respond to the questions before attending the lecture, following the principles of a flipped classroom approach. During the lecture, the instructor actively engaged both online and onsite students by prompting them with questions related to the preparatory material. Following this initial discussion, students were given additional time to discuss the text and address further questions introduced by the teacher, fostering collaborative dialogue among peers. Finally, the instructor rejoined the discussion to provide clarification and address unresolved questions. Six lessons were fully recorded to be transcribed for analysis. During the data collection, a researcher was always present in the back of the classroom to observe the lesson and note if any technical difficulties occurred. This researcher did not participate in the classroom and only noted the technical difficulties. We used two separate recording devices for backup purposes. All the data that was used was collected by these recording devices.

Semi-structured interviews

To answer the third research question, we conducted semi-structured interviews after the course was completed. All the participants were approached, and five of the six students agreed to participate in the interviews. We designed the interview protocol (Appendix B) to explore S-T and S-S interaction. We consciously aimed to keep our questions as open as possible and used follow-up questions to delve further into aspects of transactional distance. Different interview questions were used for the students and the teachers (Appendix B). Before the interview started, teachers were given a summary of the study and gave their informed consent.

3.3.4   Data and data analysis

Transactional distance questionnaire data and analysis

Since the number of participants is low, the results of all the meetings were averaged for analysis. We compared both the online and the onsite groups to each other for both the T-S and S-S interaction. We used a Shapiro-Wilks test to determine the normality of the obtained dataset. As the dataset was not normally distributed, we used a Mann-Whitney U test to determine the statistical significance of the differences between the two groups.

Conversation analysis data and analysis

Each hybrid lecture contained 20 to 45 minutes of group discussions. These discussions were transcribed verbatim and analysed. We based our analyses on turn-taking analyses which originated in conversation analyses (Sacks et al., 1974). In our transcriptions, we marked the utterings of the students and

teachers as either talking, questioning, or laughing to create an overview of the interactions during these group discussions. We have visualised these results in a scheme, showing when turns are taken. When somebody has a turn, this is shown by a square; when the turn is specifically given to somebody else, this is shown with an arrow, and when somebody takes a turn without it being specifically given this is shown by a square and no arrow.

Table 3.2 *Overview of the types of codes for both the student and teacher interview, subdivided by where the codes came from*

Student		Teacher	
Guiding framework	Interviews	Guiding framework	Interviews
Interaction_Formal_St udent Online-Student onsite (I_F_SoL-SoS) Interaction_Formal_St udent Onsite-Student onsite (I_F_SoS-SoS)	Interaction_Infor mal (I_Informal)	Interaction_Formal_St udent Online-Student onsite (I_F_SoL-SoS)	Interaction_Infor mal (I_Informal)
Interaction_Formal_St udent online-Teacher (I_F_S0L-T)	Students' opinion on hybrid education	Interaction_Formal_St udent online-Teacher (I_F_SoL-T)	Organisation
Interaction_Formal_St udent onsite-T (I_F_SoS-T)		Interaction_Formal_St udent onsite-T (I_F_SoS-T)	Technical aspects
			Teacher suggestions

Interview data and analysis

After verbatim transcription, the interviews were coded in NVivo following a "top meets bottom" approach in which a top-down and bottom-up approach are combined (Glaser & Strauss, 2017; Thorne, 2000). Some of the codes emerged from the literature, such as the types of interactions, while others, such as the informal interaction and the organizational aspect, appeared from the interviews. Different codebooks were used for the student and teacher interviews. During the coding, we refer to two types of interactions, formal and informal interaction. Formal interaction referred to all the content and lecture-related interaction, informal interaction referred to small talk, coffee machine talk, and overall talk during the breaks. The categories that emerged from both the guiding framework and the interviews are shown in Table 3.2. The categories that emerged from the guiding framework were further subdivided by adding a qualification of the affective character to the corresponding quotes: negative, neutral, or positive. Through including the codes that emerged from the interviews we avoided using non-descript categories like other. For both sets of interviews,

and coding, second coding was done on all quotes by two independent researchers. For the students, Cohen's kappa was 0.94. For the teacher interviews, Cohen's kappa was 0,84.

3.4   Results

3.4.1   Results of transactional distance questionnaires

The descriptive statistics of all the sessions combined (33 filled out by the onsite students and 5 by the online students) are represented in Figure 3.4. When we compare two constructs, teacher-students (T-S) and student-student (S-S) for the online and onsite students (Figure 3.4) we see that the onsite students always score higher on the Likert scale than the online students. Note that a high score corresponds to a lower transactional distance. A Mann-Whitney U test demonstrated a significant difference between the online and onsite students for both types of interaction ($p < 0.001$ and $p < 0.001$).
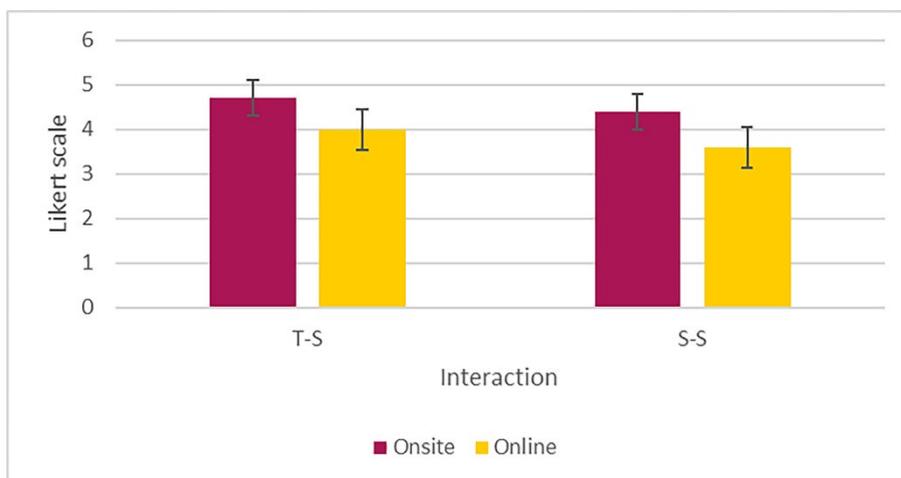
Figure 3.4 *The differences in experienced transactional distance between the online and onsite students when looking at both the teacher-student (T-S) interaction and the student-student (S-S) interaction. T-S interaction = p < 0.001 and S-S interaction p < 0.001*

Differentiated over the individual sessions, the results on transactional distance are given in Figure 3.5. In this figure, online students tend to score lower on both T-S online and S-S online compared to their onsite counterparts, in each lecture where online students were present. Figure 3.5 also shows an increase in scores between the first and second lecture. Note that no statistical test was performed on this difference.
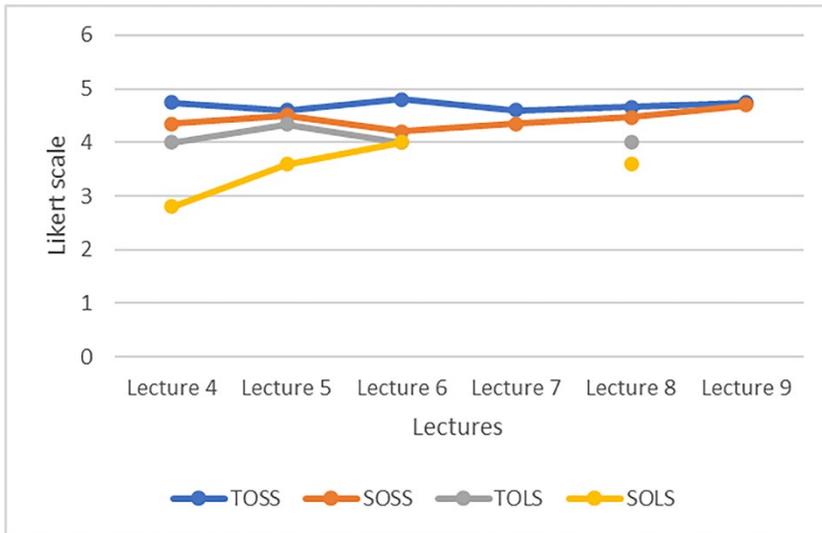
Figure 3.5 *Graph showing the average score of the different interactions related to transactional distance per meeting. Four constructs are shown in this graph, the teacher-onsite student (TOSS), the student-onsite student (SOSS), the teacher-online student (TOLS) and the student-online student (SOLS).*

3.4.2   Results from the conversation analysis

In Figure 3.6, the different interactions during the classroom discussions are shown. We have classified the students' and teachers' utterings either as talking (statements and answers), questions, or laughing. Moreover, the arrows are used when somebody specifically addresses another person. Notably, we can see that online students are often specifically addressed by either a teacher or an onsite student when they talk; 68,5% of the time that an online student talks (including questions), this is due to someone asking them a question. The onsite students, however, do not need explicit prompts to enter the discussions, as this only happens in 6,5% of the dialogue. For example, when we look at the content of the dialogue in box 1 in Figure 3.6C, we see that the onsite students start discussing a text by themselves while the teachers are switching PowerPoints; the online students do not participate in this discussion (Figure 3.7). The students were discussing a text that they all found incredibly difficult to read and were happy that they were not the only ones who struggled with the text. The online students did not participate in the conversation.
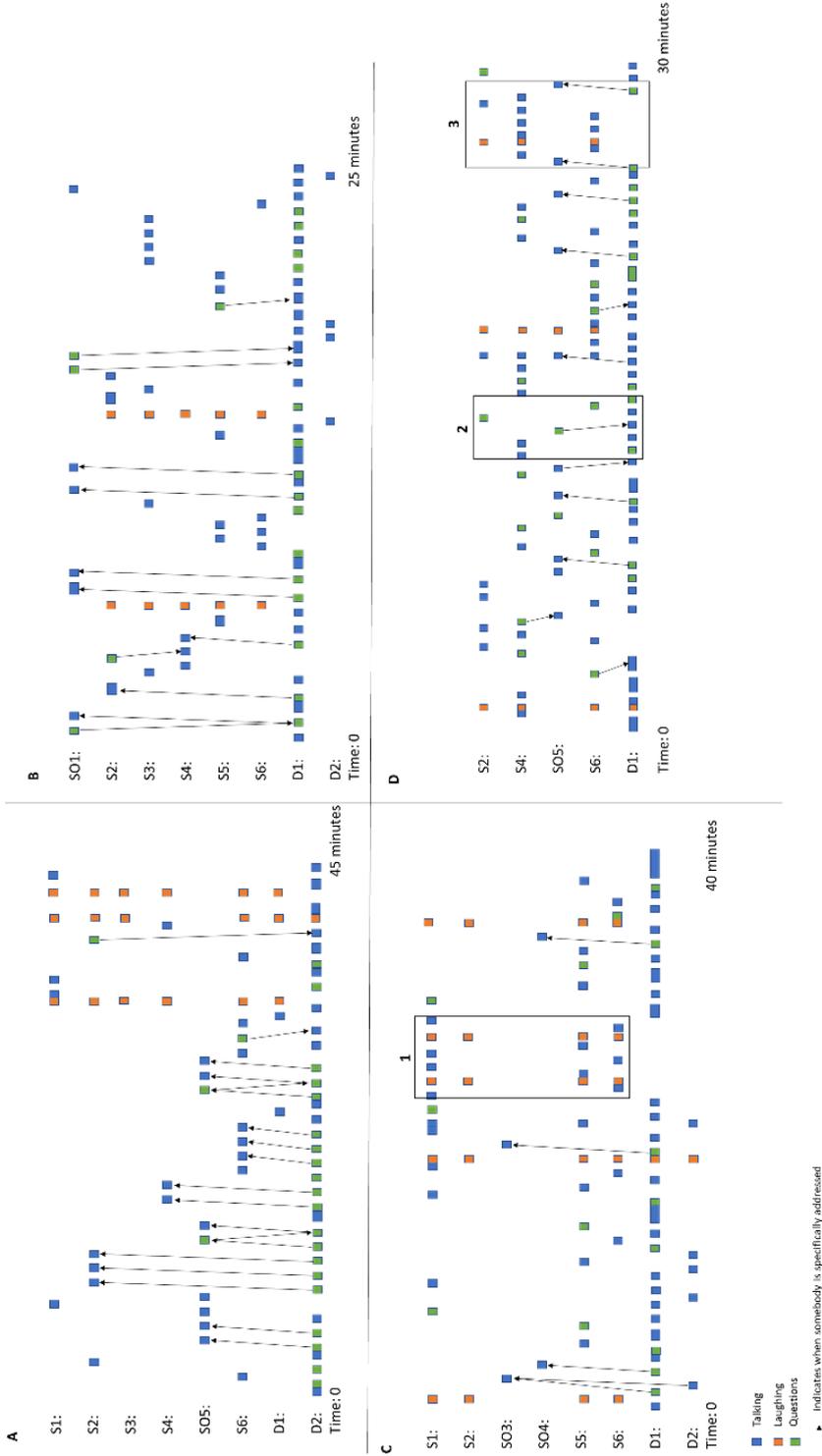
Figure 3.6 *Overview scheme of the interaction happening during four lectures. In image A, the interaction in lesson four is visible. In B, the interaction in lesson five is visible. In C, the interaction in lesson seven is visible, and in D the interaction in lesson eight is visible. The students are indicated as either S1 or SO1, with the O indicating that the student is online, and the teachers are shown as D1 and D2. Moreover, the blue blocks show when a student or teacher is saying anything, the green blocks show when there is a question asked, the orange blocks show when there is laughter in the classroom and the arrows show when somebody is specifically asked something. Furthermore, the three blocks indicated by the numbers one, two, and three show specific interactions that will be further discussed in the text.*

S1:	*"I had to read the text three times!"*
S6:	*"I read it ten times!"*
Onsite students laugh	
S5:	*"I had to go back to the beginning so many times."*
S1:	*"Sometimes I was like is this English? Because I couldn't."*
S6:	*"Yeah! Some of the sentences were weird, and then I was like this can not be what it says."*
S1:	*"I'm happy to hear I wasn't the only one who struggled."*
S5:	*"Yeah, I hoped they would us an image the illustrate it because that would make it clearer. But of course, they never do that."*

Figure 3.7 *Onsite student dialogue from Figure 3.6C box 1. The conversation was about a text students prepared for the lesson and happened while the teachers were switching between PowerPoints.*

When the online student does participate in the dialogue, the interaction is relatively short (Figure 3.6D box 2). Student dialogue (Figure 3.8) shows that the dialogue between the online student and the teachers quickly passes to another student. Moreover, online students also utter things such as: "*Could we switch microphones?*" and *"I could not follow that, could you repeat it?"*

D1:	*"So we can determine if we add them vectorially, then the left becomes weaker, and the right becomes stronger. How can we then use this to explain that the needle moves to the right?"*
S05:	*"Are those field lines directed to the right stronger?"*
D1:	*"Yes, those field lines to the right are stronger than to the left, and those field lines, depending on how hard they rotate, tend to get shorter and thicker. So, you could say that on the right the tendency to get shorter and thicker is stronger than on the left."*
S2:	*"Getting shorter? If you look to the right, you add them up and they get longer, right?"*

Figure 3.8 *Student dialogue from Figure 3.6D box 2. The conversation is about a question the teachers asked; the online students follow up with a clarifying question and then the conversation continues without the online student participating.*

Then when all students got the assignment to discuss together a question that the teacher provided, the online student did not participate in this discussion until the teacher asked them a specific question (Figure 3.6D box 3). The students are discussing this question and cannot reach agreement on an answer, the teacher interferes with the discussion and tries to involve the online student (Figure 3.9). After this, the online student participation in the discussions stops.

S4: *"Do we work together or alone?"*
S4 and S6: *"Together!"*
The onsite students laugh
S4: *"They work against each other and then they push out, no they came toward each other."*
S6: *"And then here they get weak again."*
S4: *"No, I think its something with far away."*
S6: *"Here there will be more space because there is space for them. Something changes here and nothing here and then there is more space for them and then they fall inwards."*
S4: *"So they are going to turn less?"*
S2: *"I think it is more on the right side."*
S4: *"If they are bigger on the outside then they they grow towards each other. So, towards each other? Or did I remember wrong, I feel like I am saying the opposite of what you are saying."*
D1: *"We could easily google this. There is only one person who can say with authority what two current wires do. They move in the same direction do they then attract or repel each other. S05, do you know this? Two wires going in the same direction do they attract or repel each other?*
S05: *"I think they would attract each other. But I am not an authority."*

Figure 3.9 *Student dialogue from Figure 3.6D box 3. The conversation is about a question the teachers asked; the onsite students are discussing this question and their opinions. The online student only participates once the teachers ask them specifically about their opinion.*

3.4.3 Interview results

Students

Based on the analysis of the five interviews with the students, the themes in Table 3.2 emerged. Of these 7 themes, four are divided into Negative, Neutral and Positive; this is the case for *I_F_SoL-SoS, I_F_SoS-SoS, I_F_SoL-T,* and *I_F_SoS-T*. The categories of *Attention, I_Informal* and *Students' opinion* did not include any connotations. In total, sixty-two quotes were found; twenty-two out of these twenty-five quotes were about the interaction between the online students and the teacher (*I_F_SoL-T*), making this the

biggest category. The smallest category is I_F_*SoS-SoS* with only one quote which is positive. Below we will discuss each of the codes separately (Figure 3.10).
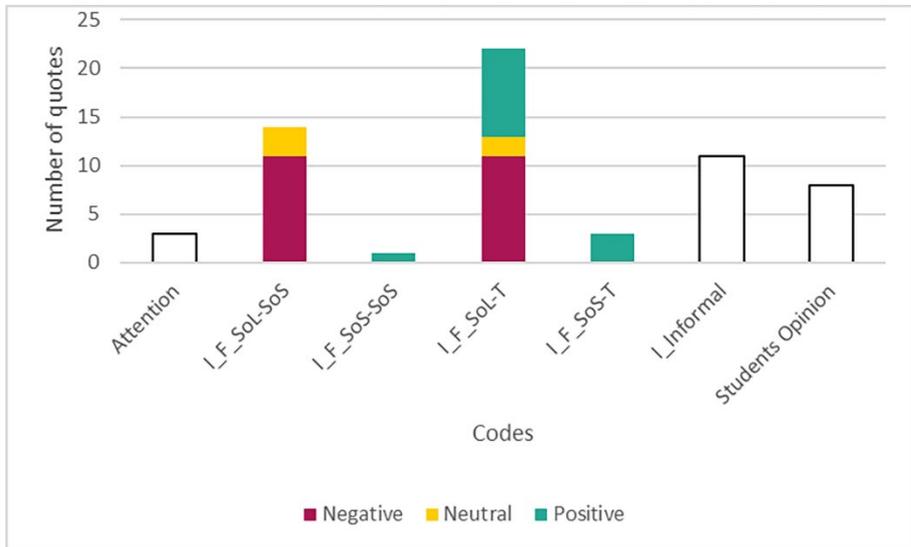
Figure 3.10 *Results of the student interviews. Distribution of the quotes over the six different categories, in which red shows negative quotes, yellow shows neutral quotes, and green shows positive quotes (N = 62). The white bars indicate quotes that have no affective connotation.*

Attention

The only time students explicitly mentioned the concept of attention was when they compared their attention span when they were present online versus when they were present in the classroom. All the students that had been present online at least once mentioned that they found it more difficult to focus and were easily distracted when they were present online, compared to when they were present in the classroom. They attributed this to them being by themselves or having more distractions at home.

Interaction_Formal

For this result section we will discuss all the codes that refer to formal interaction. These codes include *I_F_SoL-SoS, I_F_SoS-SoS, I_F_SoL-T* and *I_F_SoS-T.* Firstly, students only mentioned *I_F_SoL_SoS* either negatively or neutrally, while *I_F_SoS-SoS* was only mentioned once and positively. The onsite students mentioned that they did not experience the interactions with the online students as being equal to the interaction they had with their fellow onsite students. One student mentioned that when present online, a greater distance from his fellow students was perceived. This student

reported being less likely to ask anything or participate in group discussions. Moreover, this student also did not view the online students as fellow students, as they felt as if the interaction was only one way.

> *"I had contact with the students in the classroom, but the people were online, those people I did not have any contact with. They were part of the lecture and the content. They had their contributions, and I may have responded to that once, but minimally. So as classmates, we had little contact." – S6*

Secondly, the online students spoke about their interaction with the teacher in a negative, neutral, and positive manner (*I_F_SoL-T*). While the biggest category of quotes was referred to as positive, the students also mentioned that the threshold for asking questions was perceived as higher when they were present online and that actions related to the technology, such as unmuting, were making it a bit harder to communicate with the teacher. What the online students did experience as positive was the attention the teacher paid to them. In every lecture, the teacher specifically addressed the online students, thus giving them the feeling that they were included in the classroom and its discussions.

> *"It was different than in other courses because they took no time to ask us [the online students] questions. They always asked if we had any questions, so that was great!" – S1*

Lastly, the onsite students spoke less about their interactions with the teacher (*I_F_SoS-T*). However, all mentions of this type of interaction were found to be positive. This was due to there being plenty of time for questions and interactions.

> *"Onsite, in the classroom, was the interaction always positive. They were open for questions and discussions." – S5*

Interaction_Informal
Four out of the five interviewed students specifically mentioned the importance of the informal contact that took place inside and outside of the classroom. This included small talk before the start of the lecture, the ability to talk to each other and the teacher during the breaks, being able to get coffee together and overall getting to know each other better. The students also mentioned that this was not possible when they were present online.

Some of the onsite students hypothesized that this might be the reason they had less interaction with the online students in general.

> *"When you are present in the classroom, it is a bit easier to make a joke or exchange a look between the lectures. You do not have that when you are online." – S1*

> *"The difference is [when you are online] that you cannot join the other students when they get coffee or talk between the lectures. So that changes the atmosphere of the lecture a bit." – S5*

> *"But someone that is always at home? Yes, that is not a fellow student for me and never will be. Because it is just an image on a screen where I do not have any informal contact with." – S6*

Students' opinion on online/hybrid education

Students thought that the content was the same if they were present online or onsite. One student also mentioned that online education would always be a surrogate for onsite education. Another student called being able to be present online an enrichment in his case. Students also believed in this case the hybrid aspect of the course worked out well because they were with such a small group. They hypothesized that the group discussions that now took place would be harder to pull off if they were in a bigger group, not only due to the organizational aspects, but also because the online students thought they would not participate as much if the group were bigger.

> *"I think if your goal is to learn something more than is strictly necessary for the exam, then I think that being present in the classroom is important." – S2*

Teachers

The analysis of the interviews with the two teachers led to the following themes: Attention, Interaction_Formal_Student online-Student onsite (I_F_ SOL-SOS), Interaction_Formal_Student online-Teacher (I_F_SOL-T), Interaction_Formal_Student onsite-Teacher (I_F_SOS-T), Interaction_ Informal (I_Informal), Organisation, Technical aspects and Teacher suggestions (Table 3.2). Of these seven themes, three are divided into Negative, Neutral and Positive; this is the case for I_F_SoL-SoS, I_F_SoL-T, and I_F_SoS-T. In total, twenty-six quotes were found; out of these twenty-six quotes, eight were the Organization aspects of hybrid teaching, making this the biggest category. The smallest categories were I_F_SoL-SoS,

I_Informal and Teacher suggestions with only two quotes each (figure 3.11). Below, we will discuss each of the codes separately to give a more detailed overview of our findings.
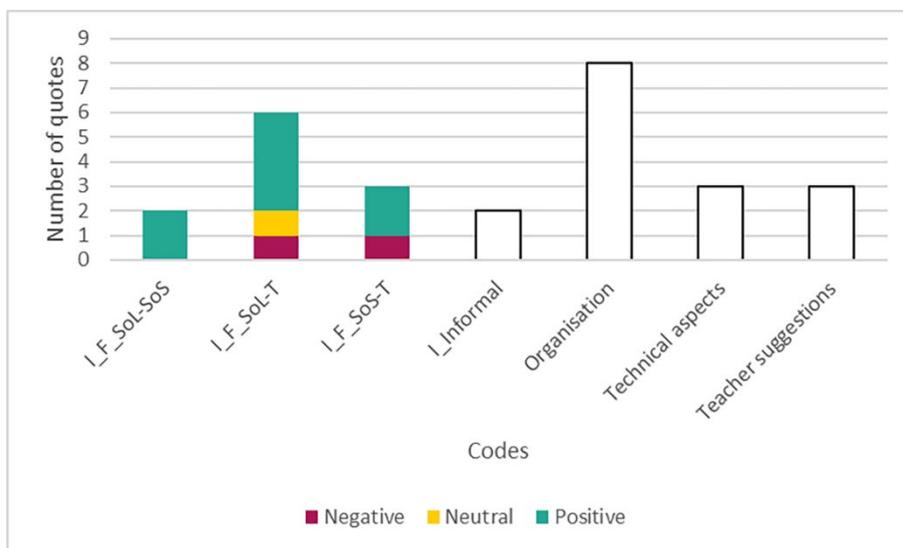
Figure 3.11 *Results from the teacher interviews. Distribution of the quotes over the seven different categories, in which red shows negative quotes, yellow shows neutral quotes, and green shows positive quotes (N = 26). The white bars indicate quotes that have no affective connotation.*

Interaction_Formal

For this result section, we will discuss the codes that refer to formal interaction. These codes include *I_F_SoL-SoS, I_F_SoL-T* and *I_F_SoS-T*. Firstly, both teachers referred to the interactions between the two groups of students (*I_F_SoL-SoS*). One of the teachers mentioned that both online and onsite students were very enthusiastic and asked a lot of questions, leading to a more inclusive environment. The teachers also reported that they realized that in some situations (in other courses) the online student could feel excluded, but that this was not the case in this group of students during this course.

> *"[the online students] always had questions and wanted to say something. The [onsite] students did not complain about the whole online aspect, [onsite students] were quite enthusiastic and nice towards the online students. Sometimes [the online students] can feel excluded for multiple reasons, however, that was not the case here." – Teacher 2 (+)*

Secondly, the teachers mentioned their interactions with the online students both neutrally and positively (*I_F_SoL-T*). Both teachers mostly spoke positively about their interaction, mentioning that there was no essential difference in interaction with both sets of students and that one online student was involved during the lectures. They also suggested that the quality of interaction with the online students might be influenced by the fact that all the students who had been present online had also been present on site at other occasions.

> *"The interaction was good [between the online students and the teacher], I had an idea of who every student was. Even more now than when you have an online student without a camera feed. And this online student asked questions via the audio, so I also knew their voices. I think that an enthusiastic online student can be part of a classroom. A timid student might say less than the online student did now." – Teacher 1 (+)*

Lastly, the teachers referred less to their interaction with the onsite student, mentioning that it was like it would be normally.

> *"There was no difference in the interaction with the onsite student." Teacher 1 (0)*

Interaction_Informal

Both teachers mentioned the importance of the informal contact with the students, stating that they would also talk to the students before the lecture, during the break and shortly after the lecture. They both implied that this informal interaction helped them to get to know the students a bit better.

> *"Somethings happen within those first interactions, as in the small things, maybe with grabbing coffee. Yes, the coffee break, because you can walk out of the classroom together and just be out of the class." – Teacher 2*

Organization

Quotes about the organizational aspect of hybrid education constitute the biggest category in the teacher interviews (8). Teachers mentioned what they thought was the biggest group size they could oversee without having too much trouble organizing the hybrid aspect of the lecture. Moreover, they also implied the need to structure lectures more beforehand to ensure that all the students had the same learning experience.

> *"If you put in the effort, then teaching in this [hybrid education] manner works." – Teacher 1*

Technical aspects

One thing the teachers sometimes struggled with was the technical aspect of hybrid education. One of the teachers reported that it was difficult to gauge a student's personality if the audio quality was compromised and that setting up all the audio and video takes more time. Again, the teachers mentioned that it takes a bit more preparation and time to get these technical aspects right.

> *"I am not that savvy with technology; I had let somebody else do it. And the thought that all [this technology] needs to be ready and working, is a threshold for me." – Teacher 2*

Teacher suggestions

Teacher suggestions included mentions of the class. The teachers mentioned that the students were interested in the topic; however, they previously had classes in which the students took more initiative than in this one. They also stressed the importance of all students being present at least in the first lecture, to establish a certain pattern to ensure that all students, online and onsite, are actively participating in the lectures. The teachers could, however, not determine what exactly that pattern was .

> *"Something happened in the beginning, in a good way, which caused us to be in the correct pattern? And then afterwards it all went correctly because we were already in the correct pattern?" – Teacher 2*

3.5 Conclusion and discussion

We revisit our research questions to phrase our conclusions.

1. How does student-student and student-teacher transactional distance develop during a hybrid university course?
2. How do online and onsite students interact during classroom discussions in a hybrid university course setting?
3. What do students and teachers report about different types of interaction in a hybrid setting?

On the first question, the online students reported experiencing a higher transactional distance than the onsite students, especially when it came to T-S. This difference between the online and onsite students remained

throughout the whole course. In general, the transactional distance all the students experienced in this course is relatively low, lower than in studies in which only online students were included. Murray et al. reported that transactional distance in hybrid education is almost the same as that experienced in fully onsite education (Murray et al., 2021). However, in this study, they averaged the transactional distance experienced by the online and onsite students, which could have influenced the average, as it is expected that the onsite students experience less transactional distance than the online students. Therefore, we cannot compare our results to their study, however, we do see a similar trend when it comes to the online group and the onsite group when we compare our results to their results on these two types of education (Murray et al., 2021). Moreover, a notable decline in transactional distance emerged for the online students between lectures four and five, coinciding with the introduction of built-in discussions. These discussions evolved during the lectures; the more comfortable the students got with each other, the more fluid and organic their interactions became (Mbwesa, 2014; Vasiloudis et al., 2015).

As for the second question on interaction, the online students needed specific prompting during the group discussions; if they were not specifically asked to participate then they would not participate in the discussions. There were some exceptions, as students did not need prompting to either report technical issues or ask clarifying questions. This was in line with previous research, in which the teachers mentioned that the technical aspect of hybrid teaching always took up a portion of the lesson (Bower et al., 2015). In our study, the teachers always specifically asked the online students questions to try to include them in the conversation. This worked to some extent; however, the online students would only participate for a short amount of time; in contrast, most onsite students would participate for a longer amount of time. Furthermore, our findings align with those of previous studies that indicate that online students tend to ask fewer questions compared to their onsite counterparts. However, contrary to some literature, our participant reported that the teachers actively involving the online students helped facilitate their interactions instead of making them feel scrutinized (Bower et al., 2015; Szeto, 2015). They acknowledged that being addressed directly by the teacher encouraged them to engage more actively than they would have otherwise. These nuanced insights suggest that while there may be concerns about potential discomfort from directly addressing online students, it can serve as a valuable tool for enhancing online students' engagement in hybrid learning environments.

For the third RQ, results from our interviews corroborate our findings when it comes to the experienced transactional distance, the change in transactional distance, and the online students being less involved in the group discussions. Both the onsite students and the teachers reported that they felt a greater distance towards the online students. Moreover, online students reported that they experienced a higher threshold during the group discussions, making it harder for them to express their opinions and participate in the discussions. Not only do online students tend to be less involved in classroom discussions, they also miss out on informal interactions, which were deemed crucial by both the students and teachers for fostering a conducive classroom environment. These informal moments, like having a coffee or chatting before and after lectures and during breaks, were highlighted by all participants in terms of building rapport and familiarity among students and teachers alike. One student specifically noted that these informal interactions, for example making a joke, exchanging a look, or grabbing a coffee together played a significant role in enhancing the group discussions during the lectures. The familiarity gained from these moments made it easier for students to share their ideas and opinions. One onsite student even remarked on feeling disconnected from their online peers, questioning if they were even a part of the classroom. These findings indicated that online students prioritize teacher interactions over peer engagement in a hybrid setting. Moreover, all students hypothesized that the absence of online students during these moments contributed to their reduced participation in group discussions. The absence of online students from informal moments such as coffee breaks limited their opportunities to build familiarity with others. Onsite students noted that this familiarity made them feel more comfortable, which, in turn, made it easier for them to participate in group discussions. The teachers echoed these sentiments, emphasizing the impact of having all students physically present in at least one lecture. While unable to pinpoint the exact reason, teachers acknowledged that seeing all the students in person at least once seemed to improve the interactions when they were present online compared to previous experiences where this was not the case. The idea that informal interaction (i.e., small talk) can influence the student's engagement is not a new concept. When students realize that they are welcomed in the classroom, they tend to exhibit higher levels of engagement and motivation, which in turn can positively impact their academic performance (Abu-Elrob & Tawalbeh, 2022). Moreover, research conducted during the COVID-19 pandemic also stressed the importance of small talk during online lectures as it leads to a more positive learning experience (Burgsteiner & Krammer, 2022;

Gnaur et al., 2020). However, when it comes to hybrid education the inclusion of small talk is more complicated as part of the students are present in the classroom and part of the students are present online. This means that the onsite students can engage in small talk, while online students do not. However, several approaches remain possible such as the use of ice-breakers at the start of a lecture or groupwork (Şat et al., 2022). Moreover, providing the possibility of small talk for all students, for example by dedicating specific time slots to small talk could also increase familiarity and thus improve classroom cohesion and thus influence the engagement of online students.

3.5.1   Limitations, implications, and future studies

The study presented here comes with limitation. First, it was conducted in a small class with only six students. However, this small setting created an environment in which classroom discussions were possible creating interaction between the students and teachers. Moreover, the small scale of this study also allowed us to be able to interview almost every participant of this study. A second limitation is the diversity of students. In our study, all the students were of the same gender. However, there was a big age range, from students in their twenties who were still full-time students to students in their fifties who were already teachers in a different field.

Our study suggests that teachers need to form an awareness of online students when teaching in a hybrid manner. It is easy to forget that there are two sets of students when you can see only one group in front of you (Szeto & Cheng, 2016; Wang et al., 2017). However, teaching in a hybrid manner requires teachers to know they have two groups of students in their classroom, the onsite students and the online students. Thus, if a teacher is aware of this, it is easier to engage with those online students. Teachers who teach in hybrid settings need to specifically engage with their online students because if they do not, chances are that the online students will not actively participate (Lakhal et al., 2021; Raes, 2022). Before a teacher even starts teaching in a hybrid setting, the technical aspects need to be addressed. In this case, the teacher is responsible for the quality of the sound and video. Especially when there are two groups of students (online and onsite), it is important to have high-quality sound and video, to create the feeling of one classroom instead of the two separate groups (Kassandrinou et al., 2014). In our study, students implied that not being able to see their online counterpart created a barrier and ensured that the online student was less included. Therefore, we would recommend the teachers stimulate the online students to turn on their cameras and make sure that the students are also visible for the onsite students. As mentioned before, it is important for the teacher to specifically include online students. Online students in our study

appreciated the teachers asking them direct questions and creating group discussions between online and onsite students. Directly asking the online students questions helps them to be actively involved in the classroom discourse (Bower et al., 2015; Lakhal et al., 2021). During our study, both sets of students implied that the group discussions were helpful, not only when it came to the content but also to feel more connected to each other. We also found that when teachers specifically addressed an online student this interaction almost always ended after the answer the student would give. Similarly, during the group discussions, the online students would never be fully part of the conversation and would only interact with the onsite students when they were specifically addressed.

Based on the results in this study we recommend that the teacher moderates these discussions to ensure that the online students will actively participate in the group discussions (Lakhal et al., 2021; Raes et al., 2020) . Moreover, both the students and the teachers in this study stressed the importance of informal interactions, before the lectures, during the breaks and after the lectures. We therefore encourage teachers to make sure that their first lecture of the course will be fully onsite before they teach in a hybrid manner. This ensures that all the students have seen each other and the teacher at least once, this should make interactions between the two groups easier. Teachers can also lower the transactional distance between online students by encouraging them to stay in the online environment during the breaks. The teacher can then turn off the sound and microphone, so the students have a safe place to talk during the break without them being projected over the speakers or interrupted by noise from the microphone. This does not decrease the transactional distance between the two groups of students. However, the teacher could ask online students how everything is going every half hour to ensure the quality of the sound and video. We hypothesize that acknowledging that there are two separate groups with different difficulties could help to decrease the transactional distance.

This study has shown the role of transactional distance in hybrid teaching; moreover, we have also shown that hybrid teaching takes more effort upfront than teaching in a traditional classroom setting. Our teachers suggested that teaching in this manner might be easier for more experienced teachers, as according to them these are more experienced with improvising when things do not go as planned. As this study was on a smaller case study, we would like to further study transactional distance and interaction on a bigger scale. Moreover, to help teachers with teaching in a hybrid manner we would like to experiment with a quick start guide to make it easier for teachers to teach in this manner. We expect that when a teacher is

adequately prepared for hybrid teaching, this will also improve the interaction and the experiences transactional distance.

3.5.2 Conclusion

In conclusion, our findings highlight that online students often require more prompting to engage in group discussions, as a lower engagement can lead to a higher transactional distance. Students express a greater hesitancy to participate in group discussions, this could be due to the absence of informal interactions, which is prevalent in the onsite environment. Unlike their onsite counterparts, online students encounter challenges in participating and initiating such interaction, which could impact their sense of belonging and participating, which could heighten the experience of transactional distance. Our study thus underscores the importance of providing online students with opportunities for small talk, facilitating connections with both their online and onsite peers could foster a more inclusive learning environment.

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Appendices

Appendix A

Transactional distance questionnaire

1. The instructor pays no attention to me.
2. I receive prompt feedback from the instructor on my academic performance.
3. The instructor is helpful to me.
4. The instructors are available to answer my questions.
5. The instructor can be turned to when I need help in the course.
6. I get along well with my classmates.
7. I feel valued by the class members in this hybrid class.
8. My classmates in this hybrid class highly value my ideas and opinions.
9. My classmates respect me in this hybrid class.
10. The class members are supportive of my ability to make my own decisions [when it comes to my reasoning]

Appendix B

Student interview protocol
-   How did you experience the hybrid aspect of this course?
-   How did you experience the interaction with the teacher?
    -   Was this different when you were online versus onsite?
-   How did you experience the interaction with the students?
    -   Was the interaction different with the online students versus the onsite students?
-   Did you experience a difference in interaction when you were online or onsite?
    -   Why?
-   Do you think the quality of the discussion depended on you being online or onsite?
    -   How so?
-   Would you follow another course in a hybrid setting?
-   Is there anything that we have not yet discussed that you would like to mention?

Teacher interview protocol
-   How did you experience hybrid education in this course?
-   How did you experience the interaction with the online students?
-   How did you experience the interaction with the onsite students?
-   Was there a difference between the two groups?
-   How did you experience the interaction between the two groups?

- Wat kind of learning activities did you use?
- Is there anything that we have not yet discussed that you would like to mention?

Chapter 4 Transactional distance revisited: A review for the case of hybrid education

Abstract Transactional distance refers to the psychological and emotional distance between teachers and students, as well as among students, shaped by dialogue, structure, and autonomy. Originally developed for distance education, its application in hybrid education remains underexplored. This systematic review analyzes 15 publications on transactional distance in hybrid learning environments to address this gap. Findings indicate that while the framework is frequently applied as background theory, it insufficiently captures the dual demands of hybrid teaching, where onsite and online learners must be engaged simultaneously. To address these limitations, we propose a model that emphasizes deliberate lesson structuring to support dialogue and interaction across settings. This model underscores the importance of balancing flexibility with planned engagement strategies. Future research should further explore and test this model to evaluate its effectiveness and adaptability in diverse hybrid contexts.

Keywords Blended learning, Hybrid education, Online education, Transactional distance

4.1   Introduction and background

Transactional distance (TD) is a concept developed to understand the dynamics of distance education and remote learning environments. Coined by Moore (1972), transactional distance refers to the psychological and emotional distance between the teacher and the student, as well as among students themselves. Over the years, this theory evolved from focusing on the teacher and the student to also including student-student and student-content interactions, leading to the ubiquitous educational triangle (Moore, 1989). While originally developed in the context of distance education, TD theory remains highly relevant in today's educational landscape, particularly as new teaching formats have emerged in response to technological advances and the COVID-19 pandemic. One such format is hybrid education, which blends online and onsite learning simultaneously, with some students being present in the classroom and others participating online in real time (Lakhal et al. 2021; Raes et al. 2020). This simultaneous delivery introduces unique challenges to maintaining interaction and engagement across both groups. As hybrid education changes how students and teachers interact, it becomes even more important to understand the psychological and emotional distance that students might experience. This is exactly what Moore's TD theory aims to describe. The word 'transactional' refers to the exchange of ideas, experiences, and knowledge among students and teachers, while 'distance' refers to the psychological distance perceived by the teacher and/or the student. TD is influenced by a variety of factors, including physical separation, isolation, differences in communication methods, and the structure of the learning environment. When students experience greater distance, their engagement decreases (Bolliger & Halupa 2018); hence, higher TD can negatively impact the learning experience, whereas lower TD fosters increased engagement, representing a positive outcome.

Moore identified three key variables influencing transaction distance: dialogue, structure, and autonomy. Dialogue is defined as intentional communication that increases learning between the teacher and the student and between students. Increasing dialogue leads to a lower transactional distance and vice versa. In contrast, increased structure leads to a higher TD because it allows for less flexibility, which likely results in reduced dialogue. Moore defines structure as the extent to which the course's design and organization are predetermined and inflexible, dictating the content and the process of the learning experience. It encompasses the rigidity or flexibility of the curriculum, instructional methods, and assessment practices. As

mentioned, dialogue and structure are inversely related, with greater structure often resulting in less dialogue, thereby increasing transactional distance. Autonomy is included in the theory to refer to the autonomy a student needs when there is a certain amount of transactional distance. In this theory, autonomy refers to students' ability to take responsibility for and control their learning process. The variable highlights the degree to which learners are capable of setting their own goals, managing time, and making decisions about their learning trajectory. When TD is high, students need more autonomy. When TD is low, and there is more dialogue, the student will need less autonomy. Students who would rather work with more autonomy would thus prefer a lesson in which there is a higher TD (Moore 2018).

Throughout the development of this concept, these three variables have remained the same, while the ways to measure transactional distance have varied. In early studies, students were asked to rate their degree of closeness or distance (Bischoff et al. 1996; Xiao 2024). The Zhang scale aimed to significantly improve the amount of detail, using a Likert-scale questionnaire of 31 items (Zhang 2003). This questionnaire included all three types of interactions—teacher-student (T-S), student-student (S-S), and student-content (S-C) (23 questions for three constructs)—with eight questions referring to the interaction between the student and the interface. In this questionnaire, 'interface' refers to the online space in general. Questions such as 'I hate using the web' are included in this category. Zhang (2003) found that the strongest construct that affected students' sense of transactional distance and engagement was the S-S interaction, followed by the T-S interaction (Zhang, 2003). However, as distance education became more technology-driven over time, Zhang's revised scale was introduced in 2015. This revised scale only included T-S, S-S, and S-C interactions and consisted of 12 items. The student-interface construct was dropped as it no longer emerged as significant due to the increased general knowledge on the use of technology. The assumption was that technology was more widespread than in 2003 and students had more experience with the needed technology (Paul et al. 2015).

Despite the long-standing relevance of TD theory, relatively few studies have explored how it applies to hybrid education. Some studies do compare transactional distance in online, on-site, and hybrid education contexts, but these often treat students in hybrid groups as one homogenous group (Kassandrinou et al. 2014; Murray et al. 2021; Vasiloudis et al. 2015). As a result, they fail to consider the potentially very different experiences of on-site and online students within the same hybrid class. The key difference

between hybrid and other forms of education is that teachers in hybrid settings must simultaneously engage two groups of students, which many find difficult (Bower et al. 2015; Ottenheim et al. 2025). Teachers often end up focusing on one group at the expense of the other, either primarily engaging with students in the physical classroom or with those online, leading to uneven learning experiences (Lakhal et al. 2021; Raes 2022; Szeto & Cheng 2016). The above considerations lead us to the following research question: How and to what extent can transactional distance theory be applied to hybrid education?

To address this research question, we will conduct a systemic review of publications that explore both hybrid education and TD. Specifically, we will analyze how these publications apply TD and explore their conclusions regarding the three core variables: dialogue, structure, and autonomy.

4.2   Systematic literature review

A systematic literature review was conducted in three databases; Scopus, ERIC, and Scholar were searched for all studies on hybrid education and transactional distance published up to 20 June 2024. The following advanced search query was applied in Scopus (All Fields), ERIC, Web of Science, and Scholar: 'Transactional distance' AND ('Hybrid education' OR 'blended synchronous learning' OR 'hyflex education'). Study selection and data extraction were performed following the flow chart in Figure 4.1. These searches resulted in 59 publications in Scopus, two publications in ERIC, one publication in Web of Science, and 293 publications in Scholar, totaling 355 publications. Non-peer-reviewed papers, conference papers, and non-English papers were excluded, leaving 181 publications. Of these papers, 57 duplicates were removed, thus leaving 124. After reading the abstracts, 61 publications were removed, as these did not match our definition of hybrid education, leaving 63 publications. After reading the introductions and conclusions of these papers, we concluded that 43 publications did not match our definition of hybrid education. This left 20 papers to be fully read, after which 5 papers were excluded due to not fitting the research question, leaving us with 15 publications (See Figure 4.1). These 15 publications were present in both Scopus and Scholar search results. These 15 papers are analyzed and discussed by the authors until full agreement was reached on the most important findings, which will be presented in the next section.
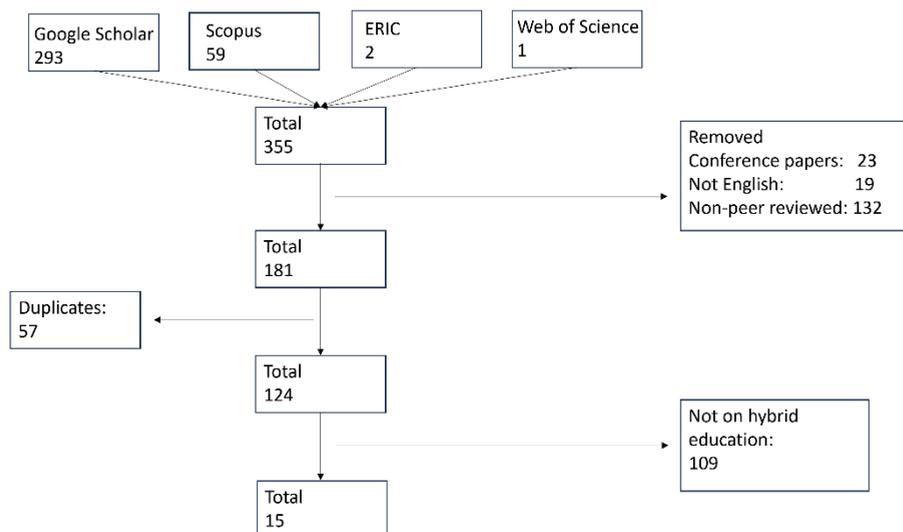
Figure 4.1 *Flow diagram of the identified, screened, and included studies on hybrid education and transactional distance.*

4.3 Results

This section presents the findings of our systematic review of 15 publications addressing hybrid education in the context of TD theory. We identified common patterns, gaps, and strategies related to the reduction of transactional distance in hybrid learning environments by analyzing these studies in terms of concepts such as interaction, dialogue, structure, and autonomy. The results are presented in Table 4.1 (below).

These publications are thoroughly examined in the following subsections, focusing on key aspects of hybrid education and TD theory. Table 4.1 serves as an overview. Then several key aspects will be discussed separately: learning dynamics in hybrid education (Section 4.3.2), Moore's three variables of TD, dialogue, structure, and autonomy (Section 4.3.3), and strategies that can help lower transactional distance in hybrid education (Section 4.3.4).

4.3.1 Systematic review table

Table 4.1 summarizes the publications included in our sample. The table follows the general structure of an academic publication, beginning with the introduction, followed by method, results, discussion, and conclusion. Within the table, dashes indicate that TD is not addressed in that particular section. When the TD is addressed in the section, it is summarized in the sections of the table.

Table 4.1. *Publications included in the review. This table displays the publications that are included in this review. The different columns represent different aspects of the publication. For example, the publication defined the concept of transactional distance (TD), which is mentioned in the framework, the RQ, the methods, the results, and the discussion/conclusions. Then, the last three columns show if and what the publications have concluded on the three core variables of transactional distance theory: dialogue, structure, and autonomy. The dashes represent that TD is not present in that section of the publication.*

Paper	Concept defined TD	Framework TD	RQ TD	Method TD	Results	Discussion/ conclusion TD	Main aspects of TD		
							Dialogue	Structure	Autonomy
Athens (2023)	--	--	--	--	Transactional distance as part of the answers given by the students when given the question: 'What was the worst aspect of this course delivery?'	Transactional distance and co-presence mentioned in relation to literature	Students were satisfied with the connection with their instructor but not with their connection with their peers, due to technological difficulties	The need for instructor preparation is paramount in terms of highly organized materials	A high percentage of failures were among first-year students who emphasized the importance of explicit self-regulatory skill within an encouraging and supportive learning environment
Bower et al (2015)	--	Transactional distance (Moore, 1993)	--	--	Co-presence mentioned in student reporting in multiple cases and cross-case analysis	Co-presence – connectedness mentioned as a pedagogy outcome and in relation to literature	The online students had a hard time communicating as they had to go through software	There was a consensus among teachers about the need to be highly organized for blended synchronous learning lessons	--

Paper	Concept defined TD	Framework TD	RQ TD	Method TD	Results	Discussion/ conclusion TD	Main aspects of TD		
							Dialogue	Structure	Autonomy
Chan (2024)	Transactional distance (Moore, 1993)	Transactional distance and Connectedness	--	--	--	--	--	--	--
Chonklina et al (2017)	Transactional distance (Moore, 1993)	Transactional distance	--	A dedicated questionnaire similar to Paul et al. (revised Zhang scale)	Results from the dedicated questionnaire similar to the revised Zhang scale	Co-presence mentioned in relation to literature	--	The instructor needs to create active learning activities and test the technology in the course environment before class implementation	--
Divanoglou et al (2018)	Transactional distance (Moore, 1993)	Transactional distance	--	--	--	Transactional distance mentioned in relation to the results and literature	A competent educator should be present in class at all times to facilitate dialogue, even when the session is primarily facilitated by an educator located at the remote campus	With careful planning, synchronous dual-campus learning environments can be an effective and attractive delivery option in tertiary education institutions	--
Francisco Pérez et al (2023)	--	--	--	--	--	Transactional distance (Shearer & Park 2019) mentioned in relation to the	--	Inadequate planning and the lack of technological support and teaching skills,	--

Paper	Concept defined TD	Framework TD	RQ TD	Method TD	Results	Discussion/ conclusion TD	Main aspects of TD		
							Dialogue	Structure	Autonomy
						results and literature		generated stress, overwork, and exhaustion in nursing professors and students	
Gleason & Greenhow (2017)	--	--	--	Make use of surveys, focus groups, and written reflections to focus on perceptions of social presence, embodiment, and transactional distance in terms of frequency of interaction, quality of interaction, and sense of closeness	--	Co-presence mentioned in relation to literature	--	--	--
Murray et al (2021)	Transactional distance (Moore, 1993)	Transactional distance	No specific RQ, but is mentioned in the hypothesis	Make use of the revised scale of transactional distance	Shows the results of the transactional distance scale	Transactional distance mentioned in relation to the results and literature	Lack of engagement; however, including course content that reduced the perceived	--	Lack of motivation

Paper	Concept defined TD	Framework TD	RQ TD	Method TD	Results	Discussion/ conclusion TD	Main aspects of TD		
							Dialogue	Structure	Autonomy
				(Paul et al., 2015)			distance, such as group work or non-course related professor and student interactions, could improve the overall learning outcomes of the students Instructors must build relationships with the students For instance, an increased use of group projects, the use of break-out rooms in online learning, and non-course related social engagements were proposed to reduce the distance		
Nussli et al (2022)	Transactional distance (Moore, 1993)	Transactional distance	--	--	--	Transactional distance in relation to how educators can promote student engagement based on the	-	-	-

Paper	Concept defined TD	Framework TD	RQ TD	Method TD	Results	Discussion/ conclusion TD	Main aspects of TD		
							Dialogue	Structure	Autonomy
						references that participants made			
Nussli and Oh (2024)	Transactional distance (Moore, 1993)	Transactional distance	--	--	--	Transactional distance in relation to literature	--	--	Learner choice emerged as a key affordance in this study
Phelps & Vlachopoulos (2020)	Transactional distance (Moore, 1997)	Transactional distance	--	--	Transactional distance mentioned as part of the quantitative findings	Transactional distance and connectedness in relation to the recommendations and literature	--	Facilitator skills should further be refined through professional development to support positive inquiry, resolution, and assessment strategies.	--
Roberts et al (2024)	--	Transactional distance (Kassandrinou et al, 2014)	--	--	--	--	--	--	--
Sat et al (2022)	--	--	--	--	Transactional distance mentioned in relation to literature	--	Web 2.0 tools are compelling technologies that can turn traditional icebreakers into dynamic and interactive online learning communities in	--	--

Paper	Concept defined TD	Framework TD	RQ TD	Method TD	Results	Discussion/ conclusion TD	Main aspects of TD		
							Dialogue	Structure	Autonomy
							which students feel free to speak, share their thoughts and ideas, and learn from each other		
Tierney, Hopwood & Davies (2023)	--	Transactional distance and connectedness	--	--	--	--	Lower engagement and motivations in online-only learning compared with face-to-face settings; the significance of domains of sociability and engagement; uneven reliability and use of technology	--	--
Wang & Huang (2017)	--	--	--	--	Transactional distance and connectedness mentioned in relation to literature	--	The challenges that caused low engagement of online learners included inadequate learner-learner interactions, insufficient learner–instructor interactions,	--	--

Paper	Concept defined TD	Framework TD	RQ TD	Method TD	Results	Discussion/ conclusion TD	Main aspects of TD		
							Dialogue	Structure	Autonomy
							limited learner–content interactions, and technological constraints. Designing group activities involving classroom and online learners would create opportunities for them to collaborate and interact with each other		

The first column of Table 4.1 demonstrates that the concept of TD is not at the forefront of these publications, despite the selection criteria. Only seven publications explicitly define the concept of transactional distance, while the other eight do mention TD theory in the literature reviews or theoretical framework, albeit only in passing. It is also notable that several publications use alternative terms such as 'co-presence' and 'connectedness' to describe concepts related to, but not identical to, TD. These terms reflect similar ideas about perceived distance or connection between students, their peers, and their teachers, without specifically referring to elements of TD theory. In some cases, TD is first mentioned in the results section without prior explanation (Athens 2023; Şat et al. 2022). These authors have assigned transactional distance as one of the codes emerging from inductive coding (e.g., Athens 2023; Şat et al. 2022). In nine of the publications, TD is mentioned in the discussion section, sometimes concerning the results (Athens 2023; Conklina et al. 2017; Murray et al. 2021). In other cases, the theory is referenced more as an afterthought (Divanoglou et al. 2018; Francisco-Pérez et al. 2023; Nussli & Oh 2024).

Within the sample, only one paper incorporates TD into its research aim, hypothesis, and methods. In this study by Murray et al. (2021), the authors use the revised Zhang scale to measure TD in online, hybrid, and on-site education to compare these three types of education. Other studies (e.g., Conklina et al. 2017) use a dedicated questionnaire similar to the revised Zhang scale, focusing on the connection between students, their teachers, and peers. However, the Conklina et al. (2017) questionnaire also focuses on the hybrid environment and how this is experienced by students (Conklina et al. 2017). Both Murray et al. (2021) and Conklina et al. (2017) refer back to their methods when discussing their findings. Murray et al. directly report on the measured transactional distance, while Conklina et al. (2017) highlight that although students were satisfied with their teacher, online students felt they lacked the same opportunities to form relationships with their teacher and peers.

Table 4.1 shows that most of the publications in the sample refer to TD in their theoretical background. However, none of these studies have used TD theory specifically in hybrid education, suggesting that it may not be fully operationalized or adequately considered in existing hybrid education research. To address this knowledge gap, we decided to focus on the components of TD theory. Therefore, we analyzed how the publications in the sample approached these interactions. We started by analyzing the interactions between teachers and students, as well as interactions among

students. Next, we explored the three core variables of TD theory: dialogue, structure, and autonomy. Finally, we will discuss the implications of the findings and strategies for reducing TD in hybrid education.

4.3.2   Teacher-Student and Student-Student interaction

Murray et al. (2021) take the position that there is little difference between hybrid education and traditional onsite education when it comes to TD. They demonstrate that the highest level of TD is experienced in online education, followed by hybrid education and then traditional onsite education. As previously mentioned, this paper considered all students, both online and on-site as a single group, which may have contributed to the outcomes reported in the publication. Moreover, their results reveal that student-teacher interactions accounted for the biggest differences in TD between the three settings. They found the modality (online, hybrid, or on-site) of the course, specifically online and hybrid, to be a confounding factor for the relationship challenges with the teachers. However, it is important to note that the (online and on-site) students in hybrid education were seen as one group, instead of the two different groups that are present in hybrid education; this could have thus influenced the results from this study.

Similarly, Conklina et al. (2017) showed that teachers who teach in a hybrid setting would sometimes forget that the online students were also 'present' in the classroom. Some of their online students reported that they did not have the same opportunities to build a relationship with their teacher as did their on-site counterparts. Moreover, one student added that their teacher would sometimes forget to acknowledge the online students. Their questionnaire results also demonstrate a low sense of community for the online group. The authors suggest that this might be due to the cognitive overload of the teacher attempting to give equal attention to both the online and the on-site students.

Even though it was not specifically measured, Conklina et al. (2017) also suggested that technology played a significant role when it came to how online students viewed their teacher and onsite peers. For example, the video or audio would not always work properly, and students felt a greater barrier due to being online. Alternatively, Nussli and Oh (2024) found that their online students did have interactions with their teacher and were satisfied with these interactions. However, they also found that communication between the online and on-site students was mostly nonexistent. Likewise, in Athens (2023), 21% of students reported that the worst part about hybrid education was the lack of connection with their

peers, even though 72% did feel a connection with their teacher. These observations illustrate two extremes when it comes to technology: either students feel connected to their teacher but not with their peers (Conklina et al. 2017; Divanoglou et al. 2018; Murray et al. 2021; Şat et al. 2022; Tierney et al. 2023), or students feel no connection with their teacher and more of a connection with their peers compared to with their teachers (Athens 2023; Nussli et al. 2022; Nussli & Oh 2024).

4.3.3   The three variables of Transactional Distance Theory

As mentioned above, only two publications in the sample specifically focused on transaction distance theory in hybrid education, even though many (N = 13) employed TD theory as a supplementary framework or an afterthought. However, numerous publications at least referenced elements of the three variables underlying TD theory. While these studies did not explicitly identify these variables (dialogue, structure, and autonomy), their findings do emphasize the significance of these variables and thus, possibly, the importance of TD by proxy. Accordingly, we will examine how these studies address each of these variables.

Dialogue

The most frequently mentioned variable in the sample of studies is dialogue. As mentioned before, multiple studies recommend using small group work or group discussions to decrease TD. The small-group work and discussion are meant to stimulate the dialogue in the lectures. Murray et al. (2021), for example, conclude that the lack of engagement could be improved by group work or non-course-related interactions, which can help improve the overall learning outcomes and learning engagement and lower the perceived distance. Similarly, Wang and Huang (2024) suggest that the inadequate interactions between the student and the teacher, as well as the limited student-student interactions in hybrid education, contribute to a higher TD for the online students. Thus, they also suggest that the teachers need to be able to create opportunities for them to collaborate and converse with each other. Bower et al. (2015) also added to the conclusions on the lack of dialogue for online students by adding that online students communicated less because of the limitations of the software used (Athens 2023). Divanoglou (2018) states that even in remote campus teaching, where one educator teaches from one location and the session is livestreamed to students in classrooms at other campuses, a separate educator should still be physically present with students at each location. This in-person presence supports dialogue and helps maintain student engagement, even when the primary instruction is delivered remotely. Overall, these findings suggest that

groupwork and effective student-to-student communication are essential for reducing TD in hybrid learning environments.

Structure

TD theory is based on the assumption that when a course is highly structured, there is less flexibility, and this will limit spontaneous dialogue in a lecture/course. In contrast, when a course design is less structured, there is more room for flexibility, and it is easier for spontaneous dialogue to occur (Moore 2018). However, whenever the publications in this study discuss the hybrid course structure and/or the preparation, they do not refer to the need for flexibility (Athens 2023; Bower et al. 2015; Francisco-Pérez et al. 2023; Phelps & Vlachopoulos 2020). Athens, for example, suggests that teachers need more preparation time when teaching in a hybrid manner, suggesting that it is essential that the lesson be highly organized (Athens 2023). The same was concluded by two other publications; without a highly organized and structured design, the teachers are reported to have less interaction with the online students (Bower et al., 2015; Divanoglou et al., 2018). Francisco Pérez et al. (2023) add that inadequate planning, organization, and lack of technological support generate extra work stress for teachers, which induces more stress during lectures. This negatively impacted both the teacher's and student's experiences (Conklina et al. 2017; Francisco-Pérez et al. 2023). Thus, teachers should have more training to be able to support this manner of preparation and teaching (Phelps & Vlachopoulos 2020). These publications thus suggest that being highly organized and structuring teaching formats, such as lectures, group work, and discussions, is essential when teaching in a hybrid learning environment.

Autonomy

The variable of autonomy in TD theory was introduced to incorporate the student's perspective. It refers to the degree to which students are required to take responsibility for their learning. High autonomy is often observed in self-paced online courses, where students have greater freedom to manage their learning independently. In contrast, low autonomy environments are characterized by greater reliance on the teachers for guidance and structure, as seen in a more traditional onsite classroom setting (Moore 2018).

From a student perspective, in hybrid education, the online component would be considered a higher autonomy environment, while the on-site classroom setting corresponds with a lower autonomy environment. As mentioned before, in the studies in the sample, the variable of autonomy itself was not explicitly named. However, related concepts such as motivation

and self-regulation were mentioned. For instance, Murray et al. (2021) found that online students often experience a lack of motivation. Similarly, Nussli & Oh (2024) noted a decrease in students' motivation when preparatory coursework was not provided before lectures. Furthermore, Athens observed that a high percentage of failures occurred among first-year students, which was attributed to their underdeveloped self-regulatory skills that are needed in such a learning environment. To summarize, these findings suggest that many online students in these studies were functioning with lower autonomy in environments that demanded higher autonomy, leading to challenges in engagement and performance.

4.3.4   Strategies to lower transactional distance

Various studies suggest that challenges such as lack of community, absence of co-presence, disconnect, or a high TD can be overcome (Bower et al. 2015; Chan 2024; Gleason & Greenhow 2017; Roberts et al. 2024; Şat et al. 2022). One way to reduce this sense of disconnect is through the use of a green screen. In this approach, the teacher is digitally placed in front of the content, mimicking a traditional classroom setting. Rather than appearing as a detached 'floating head' beside the presentation, the teacher is visually integrated within the instructional material, similar to how weather presenters appear in front of forecast graphics. This technique enhances a sense of presence and continuity between the teacher and the content. Of the online students, 80% noted that the use of this green screen improved lecture delivery and teachers' presence and that it captured their attention. The use of the green screen barely impacted the onsite students, with 91% of students reporting that their onsite learning experiences were not altered by it. One student even mentioned that even though they were present on-site, they would also follow the live stream to see the lecturer better (Chan 2024).

Another innovative way to reduce the feeling of disconnect was the use of robots. In this study, the online students' faces were visible on a screen on a robot, which was able to move around, thus creating a more embodied experience. The authors concluded that the use of the robots helped facilitate more interactions and more cross-communication between the online and on-site students (Gleason & Greenhow 2017). However, less elaborate ways to increase cross-communication and a community feel are mentioned as well, with multiple studies suggesting the use of active learning strategies. These publications hypothesize that providing online and on-site students with opportunities to work in smaller groups and engage in group discussions will foster a more connected community and will increase cross-

communication (Bower et al. 2015; Murray et al. 2021; Roberts et al. 2024; Şat et al. 2022). Şat et al. (2022) also suggest using icebreakers, such as letting students talk about their favorite quotes, which can also improve the connection students have with each other. The use of icebreakers could help facilitate the earlier-mentioned group discussions.

4.4　Conclusion and discussion

This review aimed to answer the following research question: How and to what extent can transactional distance theory be applied to hybrid education? The sample of publications resulting from our search criteria cannot give a final answer to the research question. The current sample originated from three different search engines; however, most of the publications found with our query did not adhere to our definition of hybrid education. This left us with quite a small sample. Of this sample, only a small part of the publications used TD theory as a main theory in their studies. However, the small sample size and the lack of in-depth research on TD theory in hybrid education highlight a significant knowledge gap regarding its application and relevance in this context. This scarcity of relevant literature and the limited uptake of Moore's TD theory in recent hybrid education research is notable and suggests that the theory has not been widely embraced or rigorously applied to this new educational format.

The publications show a relative lack of research on TD theory in hybrid education, and the thorough application of TD theory in this context is rare. While the reviewed studies do not provide definitive conclusions about the use of Moore's TD theory in hybrid education, many acknowledge the importance of its core variables: dialogue, structure, and autonomy. Moore's framework, despite being developed in the 1970s, remains highly relevant today, especially in the post-COVID-19 era, where distance education has rapidly expanded and evolved. However, the distinct challenges of hybrid education, catering simultaneously to both online and on-site students, demonstrate that Moore's theory requires significant modification or may not fully apply in its original form.

One main conclusion from the review is that stimulating dialogue and interaction between students and teachers is key to reducing TD. In the context of hybrid education, ensuring that online students are engaged in classroom discussions presents challenges, but it is essential to lower the transaction distance. Moreover, online students often require greater motivation and self-regulation than their on-site counterparts. The physical distance and lack of immediate face-to-face engagement can make it harder

for online students to stay engaged. The studies in this review note that teachers need to consciously design and implement strategies to foster the desired interaction among both online and onsite students. Teachers need to actively plan how to include the online students in discussions, which requires the use of technology and pedagogical techniques that allow for improved interaction (and lower TD) between the groups.

Moore argues that a less structured course is more flexible, which in turn promotes more dialogue and lowers the TD. In theory, more flexible lectures allow for greater interaction between students and teachers. However, when applied to hybrid education, this hypothesis might not hold. For instance, Lakhal et al. (2021) highlight the importance of rigorous planning in hybrid education, particularly in structuring activities and fostering interactions between the two sets of students. Unlike a traditional onsite classroom where spontaneous interactions often naturally occur (resulting in low TD), hybrid education demands a more intentional design (Lakhal et al. 2021) to lower TD. Similarly, Zydney et al. (2018) note that hybrid education requires teachers to plan for interaction with online students that might not happen spontaneously. This structured approach ensures that both on-site and online students have equal opportunities to engage (Zydney et al. 2018). This need for structure comes from the fact that teachers either forget to acknowledge the online student or focus on the students right in front of them. Alternatively, some teachers may focus too much on the online students, which leads to neglecting the on-site students (Bower et al. 2015; Lakhal et al. 2021; Raes 2022; Szeto & Cheng 2016; Wang et al. 2017). These findings challenge Moore's notion that a less-structured course necessarily reduces TD. For example, a less structured discussion could exclude the online students, either due to technical difficulties or the tendency for on-site students to dominate conversations. As a result, a more structured approach may help reduce the TD in hybrid settings by ensuring that the online students are actively included in the interactions.

This review suggests that traditional TD theory may fail to fully capture the complexities of hybrid education and may not be applicable in this context. Particularly, the need for teachers to address the distinct needs of the two separate groups of online and on-site students raises questions about the theory's validity in hybrid settings. Given this, it could be argued that Moore's theory, while foundational for distance education broadly, may need substantial revision or extension to remain relevant. Based on the publications included in this review and other relevant publications, we suggest that in the case of hybrid education, the model could be extended by

stating that a hybrid course needs to be more structured for interaction and dialogue to occur for both sets of students (Figure 4.2). Our proposed model is thus a starting point for future research on TD theory within hybrid education. Publications included in this review also suggest that an active learning method could also help reduce the TD. By putting the students (both online and on-site) into small groups and having group discussions, the feeling of co-presence and community could increase.
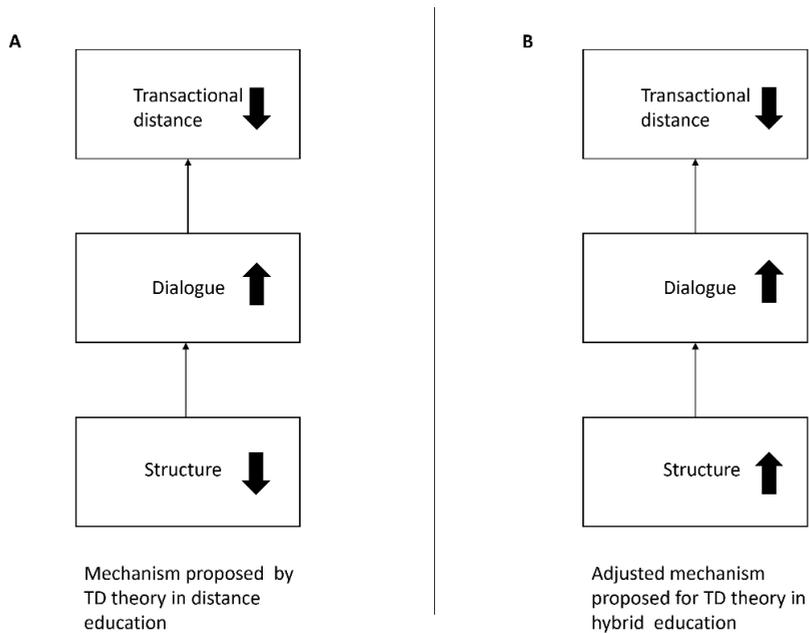
Figure 4.2 Mechanism within TD in distance education versus mechanism within TD in hybrid education. In Figure 2A the mechanism of the inverse relation between the variables dialogue and structure is present as it was originally proposed within TD theory. When structure goes down, the dialogue increases, and students perceive less transactional distance. In 2B, the proposed mechanism adjustment is visible for hybrid education. When structure increases, dialogue also increases, and the perceived transactional distance will decrease.

In conclusion, while Moore's transactional distance theory remains a foundational framework for distance education, hybrid education introduces new nuances that the theory may not fully address, as it was originally developed with fully remote or online education contexts in mind. The assumption that flexibility increases dialogue, thus reducing TD, may not apply in a hybrid setting. Moreover, our review highlights a surprising lack of rigorous application and engagement with TD theory in current hybrid education research, indicating that the theory's potential remains

underexplored. Therefore, research is needed to explore how TD theory can be better adapted to reflect the realities of hybrid education and whether our proposed mechanism would more accurately reflect the situation in a hybrid learning environment.

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Chapter 5 Bridging learning spaces across nations: Interaction and transactional distance in hybrid COIL education

Abstract   Hybrid education has gained substantial attention as a way to connect onsite and remote learners in shared experiences. Yet the format poses challenges for interaction and engagement, particularly in international collaborative contexts. To investigate these dynamics, this study examines interaction and transactional distance (TD) in a hybrid Collaborative Online International Learning course with 120 students from Dutch and UK universities. Data were collected through questionnaires, observations, and semi-structured interviews. Findings show significant differences in experienced TD, especially in student–student interaction. Hybrid sessions were perceived as more interactive than fully online sessions. Informal interactions proved essential for building relatedness, which in turn supported content-related discussions. Such interactions occurred frequently in the hybrid setting but were largely absent online. A stable audio and video connection was identified as a prerequisite. Overall, the study highlights the importance of informal interaction, reliable technology, and deliberate instructional design for effective hybrid international education.

5.1   Introduction

In an increasingly globalized educational landscape, universities seek innovative ways to foster intercultural competencies, collaborative skills, and digital literacy among students. *Collaborative Online International Learning* (COIL) is a largely online educational model that brings together students and teachers from different countries in shared, often asynchronous, learning experiences. Through joint assignments, cross-cultural dialogue, and co-teaching, COIL enriches the educational experience and allows meaningful intercultural exchange without requiring geographical proximity (Hackett et al., 2023; O'Dowd & Lewis, 2016; Rubin, 2016). The model proved especially valuable during the COVID-19 pandemic, enabling institutions to sustain international collaboration despite travel restrictions and campus closures (Hackett et al., 2023; Kara, 2021). However, while COIL offers considerable potential for inclusive internationalization, it also presents pedagogical challenges. Students often struggle with asynchronous communication, limited real-time interaction, differences in educational cultures, and language barriers (Jenssen et al., 2024; O'Dowd & Lewis, 2016). These issues can hinder collaborative relationships and lead to disengagement, especially where rich student-student and student-teacher interaction is essential (Naicker et al., 2022). Hybrid education, which synchronously blends online and onsite instruction, has emerged as a promising approach to connect learners across locations and indeed nations (Murray et al., 2021; Ottenheim et al., 2025; Raes et al., 2020). By enabling real-time interaction between onsite and remote participants, hybrid formats can facilitate informal contact, strengthen social presence, and promote inclusion (Ottenheim et al., 2025; Szeto, 2015). Hybrid models clearly have the potential to reduce the psychological and communicative barriers in online COIL (Lakhal et al., 2021; Wang et al., 2017). Empirical research on hybrid COIL education is limited. We are thus left to wonder how hybrid COIL education influences students' and teachers' perceptions of distance, interaction, and learning experiences (Hackett et al.).

Moore's theory of transactional distance (TD) provides a useful framework to understand these challenges in hybrid education (Moore, 1997). TD describes the psychological and communicative gap that can arise between learners and instructors due to limited dialogue, rigid course structure, or low learner autonomy, often resulting in reduced motivation and engagement (Karaoglan-Yilmaz et al., 2024). While TD has been widely applied in online learning research, its role in international collaborative formats like COIL, especially when combined with hybrid elements, remains

underexplored (Anzai & Shimizu, 2022; Bolliger & Halupa, 2018; Chen, 2023; Weidlich & Bastiaens, 2018). This study addresses the overall question concerning the unfolding of interaction patterns and learning experiences for students and teachers in a hybrid COIL setting, by answering the following research questions:

1. How is transactional distance experienced in a hybrid COIL setting?
2. What are the characteristics of student-student interaction in a hybrid COIL setting?
3. How do students and teachers experience a hybrid COIL setting?

5.2 Theoretical framework

This section explores key concepts from the literature on transactional distance, interaction, structure, and informal communication. These concepts directly relate to the research questions.

Transactional distance (TD) in hybrid education

TD refers to the psychological and communicative space between student and teacher, and has three dimensions: structure, dialogue, and autonomy. *Structure* refers to how the course is designed and how rigid or flexible its components are. *Dialogue* describes the extent and quality of interaction between students and instructors during the learning process. *Autonomy* reflects the level of self-direction and independence expected from students in managing their own learning. Research shows that a high TD, characterized by low dialogue, rigid structure, and high demands for autonomy, can lead to reduced motivation, engagement, and satisfaction among students (Chen, 2023; Karaoglan-Yilmaz et al., 2024)

Although widely applied in online education, TD has rarely been used as a primary framework in hybrid contexts. Most existing studies focus on either fully asynchronous or fully online education (Bolliger & Halupa, 2018; Weidlich & Bastiaens, 2018). In our systematic review (Ottenheim et al., 2025), we found that literature on TD in hybrid education is limited. Only a few studies, such as those by Raes et al. (2020) and Murray et al. (2021), explore its relevance directly.

Dialogue and interaction in hybrid education

In hybrid classrooms, interaction, or the dialogue between students and between students and teachers, is not always equally accessible to all students. Interaction is strongly linked to student engagement, which in turn influences learning outcomes (Dixson, 2015; Martin & Bolliger, 2018). Several studies show that students who attend onsite often engage more

spontaneously than those online (Raes, 2022; Wang et al., 2017). This creates unequal opportunities for contribution and involvement, especially during discussion-based activities.

The study presented here considers how interaction was experienced by onsite and online students, and how that shaped their perception of the course. We draw on the Community of Inquiry framework (Garrison et al., 1999), which adds more nuance to the role of interaction in online and hybrid learning. This model includes three forms of presence: teaching, cognitive, and social presence. Especially social presence, the feeling that other students and teachers are "real" and accessible, appears to be essential in shaping a sense of belonging. When social presence is low, students are less likely to engage and more likely to experience distance (Chen, 2023; Szeto, 2015).

Informal interaction

Dialogue is usually studied in terms of formal instruction. But informal interaction, such as small talk before and after class, can also significantly shape students' sense of connection and presence. In hybrid education, this informal layer is often lost, especially for online students who do not share the same physical space as others (Abu-Elrob & Tawalbeh, 2022; Gnaur et al., 2020). In a previous case study (Ottenheim et al., 2025), students explicitly mentioned the lack of informal interaction as a barrier to engagement. Without the possibility of casual check-ins or side conversations, online students often reported feeling less part of the group. This aligns with research on social presence, which shows that even short, informal exchanges can help students feel seen and included (Burgsteiner & Krammer, 2022; Chen, 2023). For this reason, our study pays special attention to how different students perceived opportunities for informal interaction.

Taken together, the literature suggests that hybrid education holds promise in reducing transactional distance, but also presents challenges, particularly in relation to interaction, structure, and informal connection. While transactional distance has been widely studied in online education, very little is known about how it functions in hybrid COIL formats. By applying TD theory to a hybrid COIL course, focusing structure and dialogue, this study aims to contribute new insights into how such courses can be designed to better support engagement and inclusion.

5.3 Methods

To answer the research questions, we use three different types of data. First, a validated questionnaire is used to measure perceived transactional distance from a student perspective (Ottenheim et al., 2025; Paul et al., 2015). Second, we apply conversation analysis, specifically looking at turn-taking, to observe what kinds of interactions take place during a hybrid lesson (Ottenheim et al., 2025; Sacks et al., 1974). Finally, we conduct semi-structured interviews to explore how students and teachers experienced the COIL course in terms of interaction (Lakhal et al., 2021; Ottenheim et al., 2025). By combining these three methods, we can triangulate classroom observations and participants report (Ottenheim et al., 2025).

5.3.1 Context

This study was carried out within the context of an international, interdisciplinary COIL course that brings together students from a university in the United Kingdom and a university in the Netherlands. The course main topic was the working of the brain. The COIL course was formerly delivered fully online, with students joining group work sessions individually from remote locations, some from their bedrooms, others from libraries or empty classrooms. The edition of the COIL course under study was delivered in hybrid format for the first time, with some students joining from a hybrid classroom while others participated online (Figure 5.1). The classroom was designed with active learning in mind: the teacher's desk is movable, and all online students are visible on large screens that are connected to the group tables. This setup is intended to create the feeling of working collaboratively in groups. Each course week began with an informal session designed to help students get to know one another and build a sense of social presence. In the content sessions, students attended lectures and participated in group work sessions, during which they collaborated on joint assignments. These group work sessions were the main focus of our study, and all data collection took place during these meetings. For practical reasons, this study focused on the experiences of the Dutch students, who participated onsite in the hybrid classroom group. In this perspective, the students from the UK participate remotely and are considered the online group. This setup allowed us to examine how hybrid formats influence group interaction, discussion, and collaboration dynamics in an international setting.

Figure 5.1 Image of the hybrid classroom.

5.3.2   Participants

Teachers

The course was taught by two main instructors, both male, with extensive experience in the subject matter and in facilitating COIL-based education. The Dutch classroom was specifically equipped for hybrid education, with integrated videoconferencing tools to facilitate communication and interaction between onsite and remote students. In contrast, the UK instructor conducted sessions from a standard lecture hall.

Students

In total, 120 students participated in the course, representing a diverse range of academic disciplines, including Pharmacy, Psychology, Information Technology, and Biomedical Sciences. The students, aged between 19 and 25, were enrolled at universities in the United Kingdom and the Netherlands. Students based in the Netherlands had the option to participate in the group work sessions either from a hybrid classroom on campus or remotely from home. At the UK university, a lecture hall was made available for students, students being free to also join the sessions from other locations. Prior to the start of the study, all participants were informed about the nature of the research and gave their written consent for data collection and participation in interviews. Ethical approval was granted and informed consent was collected from all participants. In the end three groups each consisting of 6 students, three from the Netherlands and three from the United Kingdom. These three groups participated in the classroom observation.

5.3.3 Procedure

The course spanned a total of ten weeks. Data collection focused on three specific hybrid group work sessions during Weeks 2, 3, and 6. While Week 1 included informal introduction sessions and technical setup, no data was gathered at that time. During Weeks 4 and 5, the course continued with fully online group work, which was not included in the analysis. After the group sessions, semi-structured interviews were conducted during Weeks 7 to 10. In table 5.1, the timeline is shown.

Table 5.1 *Course schedule and data collection*

Week	Course activity	Research activity
0	Pre-course preparations	Informed consent collected
1	Start of course	No data collected
2	Hybrid group work	Data collection
3	Hybrid group work	Data collection
4-5	Online group work	No data collection
6	Hybrid group work	Data collection
7-10	Online group work and conclusion of the course	Interviews conducted

5.3.4 Instruments

Three different data sources were used: the transactional distance questionnaire (RQ1), the conversation observations (RQ2), and the semi-structured interviews (RQ3).

Transactional distance questionnaire

We used a revised version of the Zhang scale (Paul et al., 2015). The original scale, developed by Zhang (2003), was designed to measure transactional distance in distance education and includes four constructs of interaction: student–teacher (S–T), student–content (S–C), student–student (S–S), and student–interface interaction (Zhang, 2003). Since our study focuses specifically on student–teacher and student–student interactions, we limited our analysis to these two constructs. The original items were adapted to reflect the hybrid learning environment used in this study (see Appendix A, Ottenheim et al., 2025). The questionnaire was administered after each data collection point, resulting in three measurements. Seventy students completed the questionnaire.

Conversation analysis data

During the group work sessions, students were asked to read selected texts and complete preparatory assignments prior to the sessions (Bergmann &

Sams, 2012), with the group discussion taking place during class. Many of these tasks were designed to prompt reflection on the differences and similarities between the approaches of the United Kingdom and the Netherlands, to support intercultural exchange. During the group discussions during the 1ste hybrid session the Dutch teacher was present in the classroom while the UK teacher was present online to answer questions and provide guidance. However, during the second and third hybrid sessions both the Dutch and the UK teacher where present in their own respective classrooms. Sessions concluded with a plenary moment, during which the teacher reflected on the content and either facilitated a Q&A session or invited student presentations.

Six hybrid group discussions, each lasting at least 60 minutes, were recorded during the groupwork sessions using standalone audio recorders (RQ2). A researcher was present in the hybrid classroom to observe the sessions and address any technical difficulties. The researcher did not engage with the class.

Semi-structured interviews

Semi-structured interviews were conducted after the course. Five Dutch students and both course instructors participated in the interviews. The interview protocol (Appendix B) was designed to explore themes related to student–teacher (S-T) and student–student (S-S) interaction, as well as the three components of transactional distance: dialogue, structure, and learner autonomy. We also included questions about informal interaction. Follow-up questions were used to probe more deeply into specific aspects of transactional distance and interaction. Although students and teachers were asked different sets of questions, the interviews were structured around the same core topics to ensure consistency and comparability across groups.

5.3.5   Data analysis

Quantitative data analysis

Data were averaged over all meetings. In the analysis the fully online group (N=29), the hybrid in classroom group (N=23), and the hybrid online group (N=18) were compared to each other for both the T-S and S-S interactions. We used a Shapiro Wilk test to determine the normality of the obtained dataset. As the dataset was not normally distributed, we used a Kruskal Wallis test to determine the statistical significance of the differences between the three groups (Murray et al., 2021).

Conversation analysis

Table 5.2 *Utterance types and subtypes in student and teacher interactions.*

Category	Subcategory	Visualisation
Statements	General discussion	▮
Statements	Introduction of a new argument	▮
Statements	Agreement	▮
Statements	Disagreement	▮
Questions	Question to the full group	▮
Questions	Question to a specific person	▮ →
Conversation	Conversation with a specific person	→
Informal interaction	Laughing	▮
Informal interaction	Talking about non-content related subjects	▮
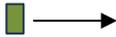
Interview data analysis

The group discussions were transcribed verbatim and analyzed. We based our analyses on turn-taking analyses which originated in conversation analysis (Sacks et al., 1974). In our transcriptions, we categorized the utterances of students and teachers as either statements, questions, or informal interactions. Each of these main categories includes several subtypes (see Table 5.2) to create an overview of the interactions during these group discussions. We have visualized these results in a scheme, showing when turns are taken and given.

After transcription, the interviews were coded using NVivo, combining both top–down and bottom–up approaches (Glaser & Strauss, 2017; Thorne, 2000). This approach enabled the use of theory-driven codes while allowing space for emergent themes. The dialogue category was divided into five distinct types and a separate category for informal interactions was used. Other codes, such as IT and Personal preferences, emerged inductively during analysis (Table 5.3). The same codebook was applied to both student and teacher interviews (Appendix C). To ensure reliability, a second round of coding was conducted by two independent researchers. Inter-coder agreement was assessed using Cohen's kappa, yielding values of 0.91 for the student interviews and 0.89 for the teacher interviews, indicating near-perfect interrater reliability.

Table 5.3 *Types of codes for both the student and teacher interviews, subdivided by where the codes came from.*

Student and Teacher	
Guiding framework	**Interviews**
Dialogue_Student online-Student onsite (D_*SoL-SoS)*	Technology aspects
Dialogue_Student onsite-Student onsite (D_*SoS-SoS)*	
Dialogue_Student online-Student online (D_*SoL-SoL)*	Personal preferences
Dialogue_Teacher-Student online (D_*T-SoL)*	
Dialogue_Teacher-Student onsite (D_*T-SoS)*	
Structure	
Autonomy	
Informal interactions	

5.4 Results

5.4.1 Transactional distance questionnaire

The Kruskal-Wallis analysis revealed no significant differences between the groups for the T–S construct (H(2, N = 70) = 0.84, p = 1). For the S–S construct, significant differences were found between Group 2 and both Group 1 (H(2, N = 70) = 9.313, p = .046) and Group 3 (H(2, N = 70) = 9.313, p = .018), indicating higher levels of S-S interaction in the hybrid in-classroom group. No significant difference was found between Group 1 and Group 3 for the S–S construct (H(2, N = 70) = 9.313, p = 1). Descriptive statistics for each group and construct are presented in Table 5.4.

Table 5.4 *Descriptive statistics for teacher–student (T–S) and student–student (S–S) per group.*

| Groups	T-S		S-S	
	Mean	Standard deviation	Mean	Standard deviation
Fully online (Group 1)	3.6	0.90	4.0	0.60
Hybrid in-class (Group 2)	3.6	0.98	4.1	0.90
Hybrid online (Group 3)	3.4	0.98	3.9	0.73

5.4.2 Conversation analysis results

Student and teacher utterances were categorized into the following interaction types: general discussion, introduction of new arguments, agreement, disagreement, questions posed to the entire group, questions directed at specific individuals, addressing specific individuals, laughter, and

informal interaction. Arrows in the visualizations indicate instances where a specific participant was addressed directly. Figures 5.2, 5.3 and 5.4 visualize the results. The other two group analyses can be found in appendix D.

As can be seen in Figure 5.2, three out of six students, including one online participant, were driving the conversation in group 1. Three of the (online) students only responded to questions, either to the whole group or directed at them specifically. Interestingly, these students also laughed when jokes were made, even though they did not engage in the discussion or the small talk.

Figure 5.3 illustrates the group discussion within Group 3. One Dutch student and the UK student participated online, while the other two Dutch students were present in the classroom. Notably, the UK student had not completed an assignment and was working on it until the final part of the discussion. As a result, the UK student barely participated in the first half of the session, during which the Dutch students switched to Dutch on two occasions. It is also worth noting that the UK student did not participate in any of the small talk, whereas the Dutch online student did. However, during the second instance, this Dutch student was unable to participate as their microphone had to be muted for personal reasons.
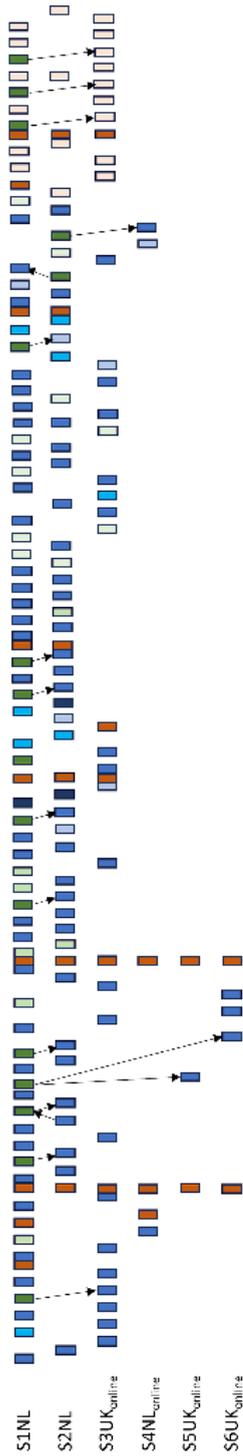
Figure 5.2 Schematic overview of interaction during a group discussion from group 1. Participants are labeled as students (e.g., S1), with national affiliation indicated as NL (Netherlands) or UK (United Kingdom); online participation is shown in subscript. Blue blocks represent general discussion, with light blue indicating the introduction of a new argument, bright blue indicating agreement, and dark blue indicating disagreement. Green blocks represent questions, where light green denotes questions posed to the group and dark green indicates questions directed at a specific individual, with arrows showing who is being addressed. Orange blocks indicate moments of laughter, and light pink blocks represent informal interaction or small talk (Table 5.2).
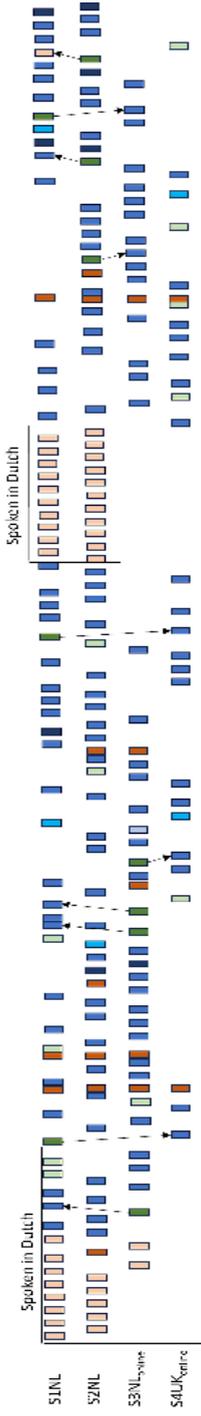
Figure 5.3 Interaction during a group discussion from group 2. For colour coding see caption of Fig 5.2. When the students spoke in Dutch, this is show by the extra bracket.
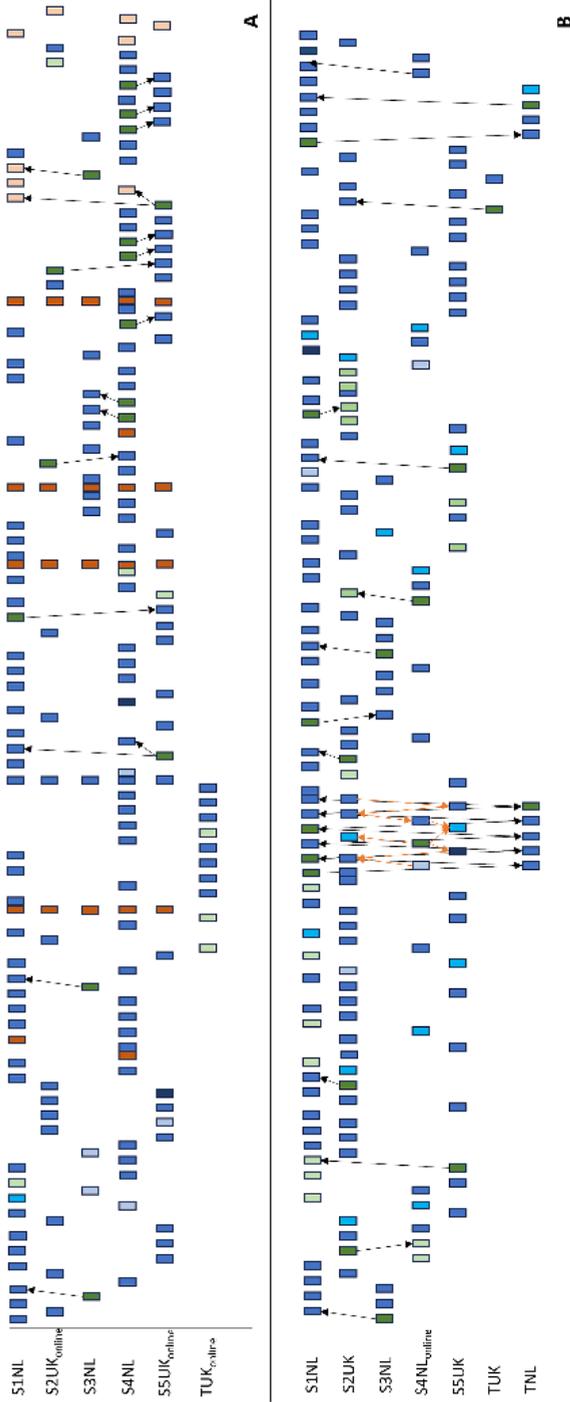
Figure 5.4 *Interaction during two group discussions from Group 3. Figure 5.4A shows the first hybrid discussion of this group, during which students also posed questions to the teachers. Figure 543B shows a second hybrid session. For color coding see Figure 5.2's caption*

Figure 5.4 Interaction during two group discussions from Group 3. Figure 5.4A shows the first hybrid discussion of this group, during which students also posed questions to the teachers. Figure 543B shows a second hybrid session. For color coding see Figure 5.2's caption

Figure 5.4 shows two discussions within the same group, on a different date. Figure 5.4A shows the group's first hybrid discussion. Notably, this group also asked questions to the UK teacher during the session. At the end of the discussion, the group engaged in small talk, which continued for ten minutes. Only the beginning of this small talk episode is shown in Figure 5.4A.

Figure 5.4B shows the second session. In this discussion, students asked questions to both the UK teacher and the teacher from the Netherlands. Conversations with the Dutch teacher took place in the classroom. During this exchange, the Dutch students in the classroom muted their microphones. The UK students and the online student from the Netherlands then started a separate, online conversation (see different colours of arrows in Figure 5.4B). Unlike the first discussion, no small talk occurred at the end of the second discussion. Notably, S3NL did not participate much during either session, despite being present in the classroom both times. S4NL showed 65% less interactions when participating online as compared to onsite. For the UK students, the difference between online and classroom participation was less noticeable. S2UK had 38% more interactions when present in the classroom, while S5UK actually had 18% fewer interactions when in the classroom compared to the first session, where both UK students were online.

5.4.3   Interview results

In the student interviews (N=5) we found a total of 70 self-contained quotes, in the interview with the teachers (N=2) we found a total of 35 quotes (Figure 5.5).

Dialogue

Both students and teachers mentioned most of the five dialogue types, but their perceptions differed notably.

Teacher-Student dialogue

Students and teachers expressed similar concerns about the challenges of online T-S dialogue. Students often felt less comfortable asking questions remotely (T-SoL): *"I don't think I've ever asked a question online [to the teacher]."* Teachers echoed this, reporting limited contact with individual students during fully online sessions. On the other hand, students

consistently reported positive experiences interacting with teachers onsite (T-SoS), feeling it was *"much easier to ask something"* and appreciating the ability to just say hello. A student summarized this (T-SoS) by saying, "*In the classroom, it feels much easier to ask something, and I just think it's nice when you can walk in and say hi to the teacher, and when you leave, say bye again, you know? So it feels a lot more personal and approachable."* Interestingly, teacher A described the onsite interactions as minimal (T-SoS), stating, *"There was hardly any at all."* In contrast, teacher B expressed mostly positive views (T-SoS), with one remarking, *"I liked having students in the classroom because I could just walk up to someone and start talking, and they kind of have to respond."*

Student-Student dialogue

As shown in Figure 5.5, students generally described fully online peer dialogue in mostly negative terms, with only one neutral comment. Teachers, however, rarely mentioned this type of dialogue, often explaining that when they entered breakout rooms, students were presenting rather than interacting naturally, making it difficult for teachers to observe dialogue. Many students felt that SoL-SoL interaction was marked by distance and hesitation: *"everyone is more distant and hesitant, like, who's going to start?"* After watching a video together*, "no one came back, no one said anything, everyone just left the meeting."* In contrast, both students and teachers reported positive experiences with onsite peer dialogue. Students mentioned that being physically at school made (SoS-SoS) interaction easier: *"I liked being at school because it was easier to talk with others."* Teachers also appreciated hearing discussions unfold in person (T-SoS), with one stating, *"What I liked were the people who were in the room. It was nice to hear the discussion."*

Hybrid dialogue, (SoL-SoS) where some students were onsite and others online, was generally viewed negatively. Students tended to feel more comfortable interacting with their peers who were physically present. One student noted, *"The students from the UK I know a lot less well, because I haven't met them in person, so that is very different from the Dutch students in my group who I did see and talk to [onsite]."* Teachers confirmed this, reporting that students referred to these hybrid interactions as *"quite challenging."*
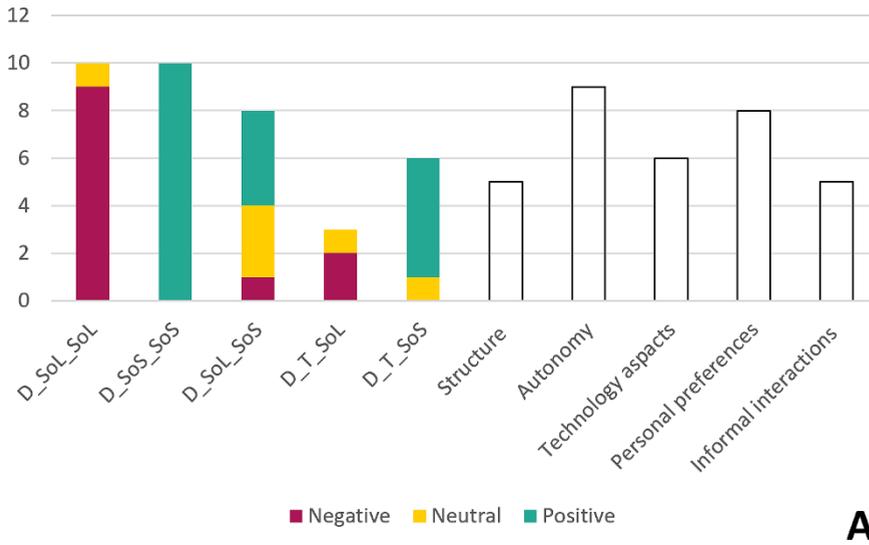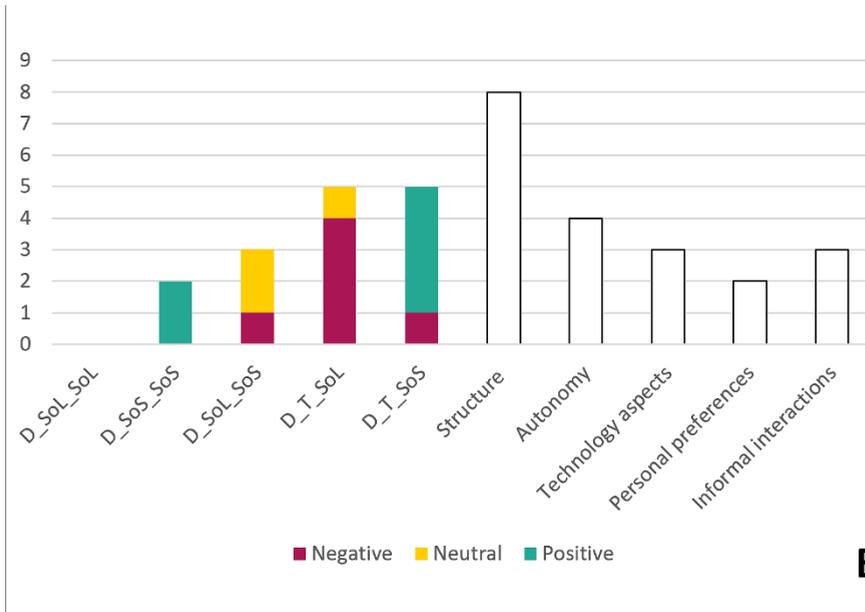
Figure 5.5 *Distribution of quotes from both student and teacher interviews. The quotes are distributed into ten categories, with red indicating a negative connotation, yellow a neutral connotation, and green a positive connotation. White bars represent categories without any affective connotation. Image (A) shows the distribution of quotes from the student interviews (N=70), while Image (B) presents the distribution from the teacher interviews (N=35). For acronyms see table 5.3.*

Structure

Some students found the course quite vague, while others felt it was well-structured. These differences often related to their academic backgrounds, as the interdisciplinary nature of the course meant students came in with different expectations and levels of familiarity. For example, one student explained, *"I thought it was kind of a vague course. A lot of the time I didn't really know what we were supposed to do, and we'd just be sitting there like, 'Uh, I guess we're supposed to discuss this?'"* Meanwhile, another student said, *"So it actually wasn't that unclear, they just said: mainly, just discuss it."*

Teachers, on the other hand, mostly reflected on their own role in (not) adapting the course to the hybrid format. One teacher acknowledged this directly, stating, *"We did not adjust our lessons to the hybrid setting,"* while the other pointed out, *"The assignments should really be tailored to the hybrid format, but they weren't."* There was also some reflection on how more structured lessons could have influenced the student-teacher dynamic. As one teacher noted, *"By structuring the lessons more, the student's independence decreases a bit, but the collaboration with the teacher increases. And I think that is what we needed to do."*

Autonomy

As for autonomy, the students reflected on the level of independence required to follow the course. Some students felt that the course offered substantial guidance, while others experienced it as largely self-directed. One student explained, *"I would give [level of independence expected] a moderate rating because we had so much guidance in our discussions… it wasn't like we could just talk about whatever we wanted."* Others, however, described a very different experience: *"I felt it was quite independent, like, here's the assignment, figure it out yourself. And then the idea was that you'd come back to the main channel and present something about it."*

Teachers, in contrast, focused more on the level of autonomy they expected from students, and how this expectation differed depending on whether students were working online or onsite. Teacher A noted, *"In the online environment, we expect more independence from students than when they work on-site."* Teacher B added, *"I expect a lot of independence from them. I expect them to understand the task they need to complete, then decide how they will approach it and determine what the final outcome will be."* At the same time, there was also nuance in how autonomy was viewed pedagogically. As teacher A expressed, *"I'm absolutely not in favor of students having to do everything completely independently. But I'm also not in favor of*

the 'I'm the teacher, you're at school, so just listen to me' attitude. For me, it's really somewhere in between."

Technology aspects

Both students and teachers reported challenges with the technology of online and (especially) of hybrid education. Common complaints focused on echoing sounds and background noise coming from the UK classroom, as well as issues with microphones and speakers not working properly, as students remarked: *"I think it's also the issue with the sound. I felt like I could focus more when I was fully online, but I got kind of distracted during hybrid sessions."* And: *"Well, like I mentioned before, the people from [the UK] were often in a room with a lot of people, so it was really noisy, and you couldn't really hear much of what was being said."*

Teachers reported differences in the facilities. Teacher A described the hybrid room in the UK as *"far from perfect, there's a lot of noise, and students sit two to a small table or so,"* contrasting this with Netherlands setup: *"I think the setup in the Netherlands is much better: one large table with a screen".* Teacher B emphasized that main problem was the noise level, which *"made it hard for them to interact face-to-face and also difficult to engage with the Netherlands through their computers."*

Personal preferences

The utterances in Personal preferences covered a broad range of perspectives, particularly from students, on different teaching formats. Many students compared hybrid and online learning, often describing hybrid as a preferable alternative, at least when they were onsite. One student reflected, *"When you're at home, it kind of feels like you're just watching a video, and now it doesn't really feel like you're actually there, you know?"* Another student expressed going the extra mile to attend onsite: *"Even though you have to travel to the university, which is kind of a hurdle to overcome, for me that's actually easier than talking to others online. So I think it could really be an improvement in the coming years, if students are open to it, to do even more in a hybrid format."* The online format, in contrast, was often associated with feelings of detachment or impersonality. One student remarked, *"I feel like if we are just going online, it's just like talking to someone you don't know. Like with social media, I guess."*

While "The students weren't exactly eager to switch to hybrid," as teacher A observed, some students still saw it as a step forward. One simply noted, "But I do like [hybrid education]. I think it's a better option than just

sitting at home behind a laptop or a computer." Teachers, on the other hand, offered fewer personal reflections in this category.

Informal interaction

Both students and teachers emphasized the important role of informal interactions and small talk in education. Students explained that being able to talk about topics beyond course content helped them feel more comfortable with each other. This comfort made it easier to express disagreement or share different opinions during discussions. Many students mentioned that informal interactions happened more naturally and frequently in the hybrid setting, whereas in fully online sessions, conversations tended to focus strictly on the course material and then ended promptly. One student described this dynamic well: *"Once you get to know each other a bit, it becomes more enjoyable and more fun […]. The material sticks better too, since school content gets mixed into conversations about hobbies or things you like or did over the weekend, then it kind of sinks in without you even realizing it."* Another added that familiarity helps ease communication: *"Once you get to know people a little, you start to understand how to interact with them, what you can and can't say. And then it becomes easier to talk to them."* A third student pointed out how feeling comfortable can lower barriers to participation: *"I think it helps if you feel at ease, you're probably more likely to say something without overthinking or holding back because you don't feel comfortable. That really makes a difference."*

Teachers also acknowledged the value of informal interaction, often focusing on its impact on group work. One teacher reflected on how a friendly and open atmosphere encourages students to share ideas without fear of judgment: *"I believe that small talk and genuinely being friendly and comfortable with others creates an environment where you feel safe to share ideas you're unsure about or uncertain of, without the fear of being judged. And I think, at the end of the day, that's incredibly important."* Another teacher stressed the motivational power of social connection: *"I think social interaction is really important because it makes students much more motivated."*

5.5   Conclusion and discussion

Let us revisit our research sub-questions. On the first research question on the experience of transactional distance in the hybrid COIL setting, we conclude that there was no significant difference in T-S interaction between fully online, hybrid in classroom, and hybrid online formats. This aligns with

previous studies suggesting that teachers consistency can mitigate perceived distance according to the format (Moore, 1993; Shea et al., 2006). This result, however, contradicts results of a previous study in which a significant difference in TD for T-S was found, favoring the onsite situation (Ottenheim et al., 2025). This difference can be attributed to class size, as in the earlier study there were only 6 students as opposed 120 students in the present study. The TD may be experienced to be lower in a small setting. Alternatively, the COIL nature of the course may have attracted a different type of student, and these students may have anticipated the online and hybrid format. As for S-S interactions, onsite students reported a lower TD compared to both their online group members and the students in the fully online groups. This was corroborated by the interview results, students describing being more reserved and content focused when joining online, whereas the students that were physically present were more inclined to engage in small talk. According to the latter, informal interaction contributed to a stronger sense of connection. This result is in line with earlier research highlighting the role of informal interaction in reducing the perceived transactional distance (Borup et al., 2014; Swan, 2002).

Concerning the second research question on the characteristics of student-student interaction in a hybrid COIL setting we observed that students actively asked each other questions, in all observed formats. In cases where students participated less compared to their peers, it was noted that these students were less vocal also in fully online contexts. This suggests that reduced participation may not just be a consequence of the setting, but rather of differences in personality (Detyna & Koch, 2023). Small talk was observed in three of the four group discussions, independent of the format. Students consistently emphasized that small talk helped them feel more comfortable and made it easier to engage in content-related discussions. This aligns with prior research that highlights the role of informal peer interaction in fostering psychological safety and collaboration (Garrison et al., 1999; Zhao et al., 2014). While earlier work (Ottenheim et al., 2025) noted the difficulty of facilitating small talk in hybrid settings due to the lack of informal transition moments (e.g. chatting before or after class), the findings in this, larger, study suggest that informal interaction is still possible when students feel ownership over the group dynamic. We conclude that hybrid formats do not inherently reduce the quality of peer interaction. When given the opportunity, students use both formal and informal interaction to build rapport and engage meaningfully with each other, even across digital and physical divides. When students are given the opportunity, they make use of

both formal and informal moments to connect with each other, even when they are not all in the same room. Note that the COIL format of the course included specific (online) meetings to facilitate small talk generally agreed that the fully online sessions felt more formal and constrained, with shorter discussions, frequent black screens and early exits being common.

Regarding the third and last research question on student and teacher experiences in a hybrid COIL setting, students perceived onsite interactions as more relaxed and conductive to learning than online ones, reporting that the added small talk helped them with the content-related discussions and thus helped them understand the content better (Detyna & Koch, 2023; Zhao et al., 2014). Doubts about hybrid education mainly stemmed from technical issues, especially the audio quality. Teachers were less positive about hybrid education, largely due to the technical issues, low onsite attendance of the Dutch students, and disconnection between the Dutch and UK teachers with the UK and Dutch students, respectively. These challenges impacted their ability to foster meaningful engagement. This is consistent with prior research indicating that hybrid learning environments often weaken social presence, even when cognitive and teaching presence remain strong, exacerbated by technical issues (Garrison et al., 1999; Vaillancourt et al., 2022). Nevertheless, when connection quality was sufficient and both student groups were present, students and one teacher described richer interactions. In-person small talk and spontaneous engagement were cited as crucial for creating a comfortable atmosphere (Ottenheim et al., 2025; Zhao et al., 2014). Interestingly, neither students nor teachers placed much emphasis on the COIL component of the course. Rather than seeing it as a core aspect that shaped their interaction, they viewed it more as the context in which the course happened to take place. This perception may explain why their reflections focused mainly on general aspects of the hybrid setup, such as interaction quality and technical challenges, rather than on the international or collaborative dimension of COIL. Both teachers mentioned that aspects like teacher-student interaction could have improved if they had adjusted their teaching methods and format. These findings highlight that the success of hybrid settings depends not only on pedagogical design, but also on reliable technical infrastructure and deliberate efforts to foster a sense of community.

5.5.1   Limitations, implications, and future studies

This study comes with limitations. During the obtaining of informed consent, the UK students chose not to participate in the interview part, so our data only reflects the perspectives of the Dutch students. However, we did

interview the UK teacher, who shared insights about their students, including the observation that they found their UK students to be less mature than the Dutch ones. This helped ensure the UK perspective was not entirely excluded. A strength of our study is the diversity among students, who came from different countries and bachelor's programs. This diversity also posed a minor challenge, as students were accustomed to different academic expectations, leading to varied opinions on autonomy, some were used to working very independently, others less so. Furthermore, the participating teachers did not adapt their teaching to the hybrid format, which they themselves acknowledged as a shortcoming. This can be seen as a strength as this also shows a very realistic situation in which teachers do not always adjust their education to the environment in which they are present.

This study highlights several important considerations for designing hybrid COIL courses and hybrid courses in general. First and foremost, success of hybrid learning depends on the technical infrastructure. Poor audio quality and other technical barriers can significantly undermine social presence and student motivation (Ottenheim et al., 2025; Vaillancourt et al., 2022). Investing in high-quality audio-visual equipment and providing technical support are essential for maximizing engagement in hybrid settings. This is especially important in setting in which students never see each other in real life (Ottenheim et al., 2025), such as COIL courses. Second, fostering opportunities for informal interaction, such as small talk, is crucial for strengthening peer connections and reduced transactional distance in hybrid or online situations (Borup et al., 2014; Zhao et al., 2014). Course designers and teachers could intentionally create spaces and moments that encourage casual conversation and community building (Garrison et al., 1999). Third, hybrid settings require a specific pedagogy. By designing moments in which the students interact with the teacher and by building in regular feedback moments the T-S interaction can improve, thus lowering the transactional distance (Borup et al., 2014; Shea et al., 2006).

This study has highlighted key factors influencing transactional distance in hybrid COIL settings, emphasizing the importance of informal interaction and high-fidelity sound and video. Future research could expand to larger and more diverse samples to explore how these findings generalize across disciplines and student populations. Additionally, it would be valuable to perform design research on fostering informal interactions and building communities in hybrid environments. For example, experimental studies could test the impact of structured small talk sessions or digital social spaces on peer connection and engagement. Another promising direction would be

to develop and evaluate targeted training or quick start guides for teachers to enhance their facilitation skills and technical preparedness in hybrid settings. Providing teachers with practical tools based on the results of this and other studies can reduce transactional distance and improve both T-S and S-S interactions, ultimately enhancing the hybrid learning experience.

5.5.2   Conclusion

In conclusion, in answering the overall question on interaction patterns and learning experiences in a hybrid COIL setting, our findings show that T–S interaction is consistent across fully online and hybrid formats, but S–S interaction significantly improves when students are onsite. This is largely due to the possibility of small talk, which helps students feel more connected and reduces transactional distance. Both teachers and students perceived fully online sessions as more formal and less engaging, while in-person settings fostered a more relaxed atmosphere that supported their learning. However, technical issues, especially poor audio quality, pose significant challenges in hybrid setting, affecting engagement and satisfaction. Neither teachers nor students focused on the COIL aspect in this course and saw that more as the context the course took place in, rather than an important aspect that influenced their interaction. These findings highlight the need for robust technology and deliberate strategies to improve community building across online and onsite environments.

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Appendices

Appendix A

Transactional distance questionnaire

- The instructor pays no attention to me.
- I receive prompt feedback from the instructor on my academic performance.
- The instructor is helpful to me.
- The instructors are available to answer my questions.
- The instructor can be turned to when I need help in the course.
- I get along well with my classmates.
- I feel valued by the class members in this hybrid class.
- My classmates in this hybrid class highly value my ideas and opinions.
- My classmates respect me in this hybrid class.
- The class members are supportive of my ability to make my own decisions [when it comes to my reasoning]

Appendix B

Interview protocol Students

- How did you experience hybrid (in-class) education?
  - What did you enjoy?
  - What were the challenges?
- How did discussions go when you were online or in a hybrid format?
  - Did you feel as engaged with your classmates as when you were fully physically present?
  - Do you think hybrid education affected collaboration and group dynamics? How?
- During discussions, was it always clear what was expected of you?
- What do you think of the level of autonomy expected from you in group discussions?
- Was there a difference in contact with the teacher when you were online versus in the classroom?
- What role do informal interactions play in your sense of connection with the group?
  - How did the MAD sessions contribute to this?
- Is there anything else you would like to share on this topic?

Interview protocol Teachers

- How did you experience hybrid (in-class) education?

- o What did you like about it?
- o What were the challenges?
- How did discussions go when you were hybrid versus online?
  - o Did you feel just as connected to your fellow students as when you were fully physically present?
  - o Do you think hybrid education affected collaboration and group dynamics? If so, how?
- During discussions, was it always clear what was expected of you?
- What do you think of the level of autonomy expected from you in group discussions?
- Was there a difference in how you interacted with the teacher when you were online versus in the classroom?
- What role do informal interactions, such as small talk, play in your sense of connection with the group?
  - o Was this different hybrid versus online
  - o How did the MAD sessions influence this?
- Is there anything else you would like to share on this topic?

Appendix C

Table 5.5 Codebook, describing ten coding categories and showing examples for each of them. With five categories divided into Negative (-), Neutral (0) and Positive (+). After each example it is shown whether it is considered negative, neutral or positive.

Code	Description	Examples
D_T-SoL	This code describes quotes that talk about the interaction between online students and the teacher. This code can be categorized as negative, neutral, or positive. Negative means that they talk about the interaction in a negative manner.	N: the online students did not answer when I asked them questions 0: The interaction with the online students was the same as the onsite students P: The online students gave really good answers to my questions
D_T-SoS	This code describes quotes that talk about the interaction between onsite students and the teacher. This code can be categorized as negative, neutral, or positive. Negative means that they talk about the	N: They did not participate well in the class 0: the discussions were okay P: The class participation was amazing, they were so involved.

Code	Description	Examples
	interaction in a negative manner.	
D_SoL-SoS	This code describes the quotes that talk about the interaction between the online and the onsite students. In this case, it also describes quotes that compare the two groups. This code can be categorized as negative, neutral, or positive. In this case, negative means that the quotes mention something negative about the interaction with the online students. Neutral means that the quote does not have a specific value. Positive means they have something positive about online students.	N: It was really difficult to get the two groups to interact 0: Both groups were just students, I do not see a difference between the groups P: It was nice to see how involved all the students were and how they tried to discuss things as a group
D_SoS-SoS	This code describes quotes that talk about the interactions between the online students themselves. This code can be categorized as negative, neutral, or positive. Negative means that they talk about the interaction in a negative manner.	N: I did not have any interaction with the other online students. 0: I sometimes spoke with the other students online. P: I enjoyed when we could work in groups online.
D_SoS-SoS	This code describes quotes that talk about the interactions between the onsite students themselves. This code can be categorized as negative, neutral, or positive. Negative means that they talk about the interaction in a negative manner.	N: I was not included in the conversations in the classroom. 0: we had some group discussions with the students in the classroom. P: I really enjoyed the discussions with my classmates in the classroom.
Autonomy	This code describes quotes that talk about the autonomy of the students.	I had a feeling that the online students needed more guidance than the

Code	Description	Examples
		students in the classroom.,
Structure	This code describes quotes that talk about the organization and structure of the lecture.	I had to structure more, and make sure I planned some interactions.
Technological aspects	This code describes quotes that talk about the technical aspects of the lecture. Think about the audio and the video, but also the connection	The microphone kept on failing
Informal interactions	This code describes quotes that talk about informal interactions. This means interactions that do not include the subject matter of the course and specifically talk about interactions that are not subject-related.	I think getting coffee was essential for the students to get to know each other
Personal preferences	This code describes quotes that describe the students and teachers preferences when it comes to education.	I preferred hybrid to fully online

Appendix D
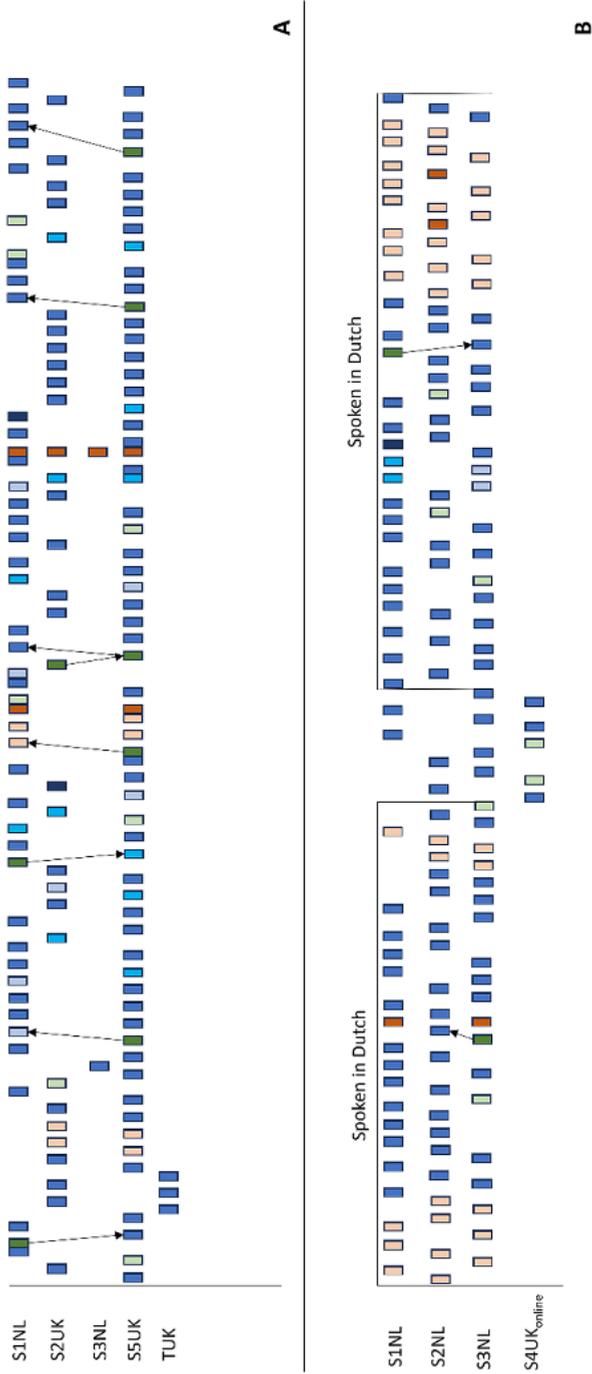
Figure 5.6 *Interaction during two group discussions. Figure 5.6A shows the hybrid discussion of group 3, during which students. Figure 5.6B shows a hybrid session for group 2. For colour coding see Figure 5.2's caption.*

Chapter 5

Chapter 6 Discussion

6.1   Introduction

Hybrid education has increasingly become a central topic of discussion in recent years as educational institutions worldwide are rethinking teaching models (Raes et al., 2020). Prior to the COVID-19 pandemic, hybrid learning which blends online and onsite teaching was mostly regarded as a flexible alternative or a complementary option to fully face-to-face education (Bower et al., 2015; Lakhal et al., 2021). It was often used to provide students with more choice and adaptability in how they access course content. However, the onset of the pandemic forced a sudden and widespread shift toward fully online learning formats, pushing educators and institutions to make rapid adjustments with little preparation time (Drijvers et al., 2021). This abrupt transition exposed both the potential benefits and significant challenges of hybrid education (Raes, 2022; Wang & Huang, 2024). For example, hybrid models can offer accessibility and flexibility but they also bring complex issues related to student engagement, equitable participation, and effective communication (Szeto & Cheng, 2016; Zydney et al., 2018). Now, as we move past the emergency remote teaching phase and begin to implement more stable hybrid systems, it is essential to carefully examine how these models function in real-world settings. Understanding what strategies help bridge the physical and psychological gaps between online and onsite learners, what obstacles persist, and how teachers and students perceive and adapt to hybrid environments is critical. Our research aims to contribute to this deeper understanding by focusing on the concept of transactional distance (TD) which refers to the psychological and emotional distance students may experience toward their peers and instructors and exploring how this distance plays out in hybrid education. Through this focus, we aimed to shed light on the dynamics of interaction and connection in hybrid learning which remain key to its success. The overarching goal was to explore the practical challenges that occur during hybrid education and how we can overcome these challenges. Moreover, we also aimed to explore the role of TD in hybrid education and how it impacts interaction, engagement and learning experiences for both online and onsite students. To investigate this, we drew on four studies, each focusing on a different perspective or context:

- In study 1 we examine the reported experiences of STEM teachers with hybrid education during the COVID-19 pandemic.

- In study 2 we delve into perceptions of interaction quality and TD from both student and teacher perspectives in hybrid. Moreover, within this study we also focused on interaction patterns that occur during hybrid discussions.
- In study 3 we challenged and extended Moore's TD theory, which has been a key framework for understanding distance learning, by testing its fit and limitations in hybrid education.
- In study 4 we focus on a hybrid Collaborative Online International Learning (COIL) course, providing insights on how TD unfolds when students from different countries learn together, both onsite and online. A second focus of this study was the interaction patterns and how informal interaction play a role in this.

In this chapter, we revisit the overarching goal and show how the results from the four papers together advance our understanding. Then, we explore key conclusions and relate them back to existing literature, highlighting where we confirm or add to what is known. We discuss strengths and limitations of the combined work, consider both scientific and practical implications, and finally, we reflect on the implications for the future of hybrid education and research.

6.2   Revisiting the overarching goal

The overarching goal of this research was to explore the practical challenges that arise during hybrid education and to identify ways to overcome them. Additionally, we aimed at understanding the role of TD in hybrid education, and how it affects interaction, engagement, and learning experiences for both online and onsite students. To address this, we conducted four studies, each offering a distinct perspective or context.

Study 1 focused on the student experience during the rapid transition to hybrid learning triggered by the COVID-19 pandemic. This study highlighted how teachers managed synchronous onsite and online education, emphasizing flexibility as a crucial factor. The insights from this paper provided a foundational understanding of the real-world challenges and benefits students face in hybrid environments, setting the stage for deeper exploration of interaction and engagement. Study 2 examined students' and teachers' perspectives, bringing to light the importance of teacher presence and instructional adaptations in hybrid settings. The findings underscored that teachers' ability to adjust their methods significantly influences TD and student engagement. Moreover, this study also showed the importance of informal interaction and the role these play in students feeling comfortable

enough to partake in classroom discussions. The literature survey in Study 3 focused on TD and patterns of interaction in hybrid education. This study suggests that the use of TF theory in hybrid education might be in need of some repair and that certain mechanisms, such as how structure influences dialogue, might need revaluation for the theory to be fully applicable in hybrid education. Study 4 delved into the critical roles of informal interaction and technological quality within large, hybrid international courses. It revealed that small talk and reliable technology are essential for building social connection, lowering TD, and enhancing engagement. This study also shows that when the technology is working correctly, it is possible to have group discussions (even in an international setting) and that these discussions can improve the learning engagement of the students.

From the four studies combined, two main conclusions stand out. First, interaction quality and engagement in hybrid education hinge heavily on the presence and quality of informal social interactions. Across multiple contexts, both students and teachers emphasized that small talk and casual moments of connection are not just "nice to have," but essential for building trust, comfort, and ultimately meaningful learning interactions. When students are onsite, these informal exchanges occur naturally and help reduce the TD between peers. In fully online or poorly supported hybrid settings, these informal moments tend to be absent, leading to a more formal, constrained, and less engaging experience. This conclusion reinforces and extends previous research that underscores the social dimension of learning (Borup et al., 2014; Garrison et al., 1999; Zhao et al., 2014). The second main conclusion is that technical quality and pedagogical design critically influence the success of hybrid education. Reliable technology, especially clear and stable audio and video connections, is foundational; without it, engagement suffers regardless of pedagogical effort. Moreover, teachers' ability and willingness to adapt their teaching methods to hybrid formats, such as intentionally creating spaces for informal interaction and increasing opportunities for teacher-student feedback, affect TD and learning outcomes. These findings highlight that hybrid education is not automatically equivalent to onsite classroom teaching, but requires deliberate design and infrastructure to succeed. Together, these conclusions emphasize that the challenges of hybrid education are twofold: social and technological. Addressing only one side is insufficient; successful hybrid learning depends on combining high-quality technology with deliberate efforts to foster informal interaction and community.

6.3   Implications

This dissertation offers insights that are both theoretical and practical in nature. On the theoretical side, it advances our understanding of hybrid education and transactional distance, refining existing models and highlighting previously overlooked dynamics. Practically, it provides actionable guidance for teachers, course designers, institutions, and students, emphasizing strategies that can reduce transactional distance, enhance engagement, and foster inclusive learning environments. The following subsections detail these contributions.

6.3.1   Theoretical implications

Our findings relate closely to and extend existing literature on hybrid education and TD. Moore's TD theory continues to provide a valuable framework for understanding the importance of teacher presence and interaction in reducing psychological distance (Borup et al., 2014; Shea et al., 2006; Xiao, 2024). Consistent with prior work (Garrison et al., 1999; Zhao et al., 2014) informal peer interactions emerged as vital for building trust, psychological safety, and meaningful engagement, regardless of students' physical or online presence. Recent studies also highlight the dual social and technical challenges of hybrid learning (Vaillancourt et al., 2022), underscoring that reliable technology, equitable access, and classroom visibility remain critical factors for enabling effective interaction and learning. Our research confirms these findings while further emphasizing the importance of emotional presence and teacher visibility, aspects less discussed in previous literature.

This dissertation, however, also makes several theoretical contributions to the research field of hybrid education and the broader discourse on TD. Building on Moore's (1989) interaction triangle and subsequent literature (Garrison et al., 1999; Szeto & Cheng, 2016), we propose a new interaction model, Hybrid Education Interaction Model (HEIM) which better reflects the complexity of hybrid learning environments (Ottenheim et al., 2025). Unlike traditional models, this framework (Figure 6.1) accounts for the simultaneous presence of online and onsite students, highlighting how these students can interact with the students within either the online and/or onsite sphere.
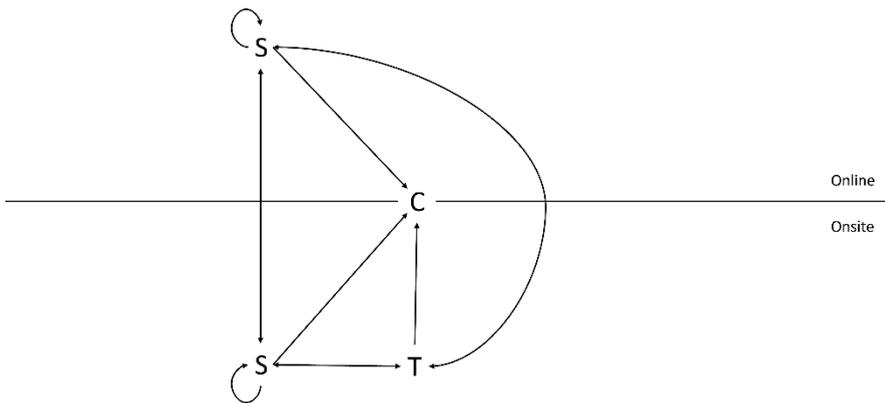
Figure 6.1 *Hybrid Education Interaction Model (HEIM). Guiding framework designed to represent the different types of interaction that can take place in a hybrid lesson. C stands for content, S stands for students and T for teacher.*

Importantly, study 2 is the first study that assesses TD separately in both online and onsite student groups within hybrid education. This analysis revealed significant differences in the TD experience by the two groups, a nuance overlooked in prior research. Earlier studies often treated hybrid education as a single unified group when comparing it to fully online or onsite formats, sometimes concluding that hybrid education was nearly equivalent to traditional onsite education (Murray et al., 2021). However, by not differentiating between online and onsite participants, these studies may have inadvertently masked disparities, as the experiences of the two groups could cancel each other out, giving a misleading impression of equivalence. Moreover, our research also refines Moore theory of TD (Moore, 1997), specifically for the case of hybrid education. While Moore emphasized the invers relation between dialogue and structure our findings emphasize the importance of structuring interactions within hybrid education. In hybrid context, teachers are expected to manage multiple channels of interaction simultaneously, balancing attention between online and onsite participants. Rather than viewing structure as a potential barrier to dialogue, our evidence indicates that well-planned course structures can actively reduce TD within a hybrid setting. This suggests a nuanced reinterpretation of TD theory, especially for hybrid education: structure and dialogue for not operate in opposition, but as interdependent mechanisms that influence TD in complex ways.

While TD theory provides a strong framework for analyzing dialogue, structure, and learner autonomy, it does not fully capture the socio-emotional dimension of interaction. Research on social presence

complements TD by emphasizing the importance of perceived psychological closeness, emotional safety, and interpersonal awareness for engagement in hybrid and online environments (Kreijns et al., 2024; Richardson, J. C., Maeda, Y., Lv, J., & Caskurlu, S. 2017). Several findings in this dissertation, particularly those related to online students' experiences of disconnection and limited visibility during class, align with these social presence constructs. Integrating TD and social presence offers a more holistic understanding of hybrid learning, illustrating how engagement depends not only on structural design but also on the quality of socio-emotional interactions. This combination helps explain why online students can be "present" yet still feel excluded or less engaged, highlighting the need for deliberate attention to both the structural and relational dimensions of hybrid learning

A further theoretical contribution is the elevation of informal peer interaction. Previous studies have documented its importance in traditional onsite settings (Abu-Elrob & Tawalbeh, 2022; Bambaeeroo & Shokrpour, 2017; Rocca, 2010), but hybrid education research has largely overlooked it. Across multiple studies, students reported that informal interactions, brief conversations before or after class, peer check-ins, or casual chat during session, were essential for building trust, reducing social isolation and enhancing engagement. For example, in study 2 and study 4, students explicitly linked these interactions to better understanding of course content and increased willingness to participate in group tasks. These insights indicate that social and emotional dynamic are central to hybrid learning, nor merely supplemental. Social presence theory also helps contextualize these findings, showing that even brief informal exchanges contribute to learners' perceived psychological closeness, emotional safety, and engagement, and are significantly associated with satisfaction and learning in online and hybrid environments (Richardson, Maeda, Lv, & Caskurlu, 2017). Taken together, these findings position hybrid education as a distinct pedagogical form, rather than a compromise between online and onsite teaching. By extending the interaction model and reinterpreting Moore's TD theory, this dissertation offers a more complete conceptual framework for studying hybrid learning in increasingly diverse educational contexts. These insights contribute to a broader conversation on equity, accessibility, and the evolving nature of presence in hybrid education. The results also provide a foundation for future research to explore how specific interventions, such as structured informal interactions or scaffolded online participation, can further refine our understanding of transactional distance and engagement. Overall, this dissertation does not aim to reject existing theories, but it does point to the

need for adaptation; as educational formats continue to shift, our theoretical tools should also evolve to remain relevant.

6.3.2 Practical implications

Beyond theoretical contributions, this dissertation offers actionable insights for teachers, course designers, institutions, and students. Hybrid education requires deliberate pedagogical, technical, and social choices to reduce transactional distance, strengthen engagement, and create inclusive learning environments. While many of these recommendations may seem straightforward and also applicable to both traditional onsite and online education, our studies show that they are not always implemented consistently. Moreover, our findings indicate that challenges teachers and students encounter in traditional onsite or online settings are often amplified in hybrid education, making deliberate design and facilitation even more critical.

For teachers:

- Be aware that online students are more vulnerable to TD. They may feel less seen and less engaged, even when participating synchronously.
- Actively include online students in discussions and decision-making moments during class. This requires planning and deliberate facilitation.
- Make expectations clear and communicate them across both groups. For example, let students know whether interaction is expected to happen in the chat, via audio, or in breakout groups.
- Consider using teaching assistants or co-teachers to help manage both the online and onsite spaces. This can help make the hybrid environment more balanced and inclusive.

For course designers and institutions:

- Design learning activities that encourage meaningful interaction between online and onsite students. This includes both formal (group work, assignments) and informal (check-ins, peer feedback) moments.
- Invest in technology that supports interaction. Sound, camera angles, and visibility matter, especially for creating a sense of inclusion.
- Provide training and support for teachers who are expected to work in hybrid formats. Managing a hybrid classroom requires different skills than teaching fully onsite or fully online.
- Consider the physical setup of the classroom. A well-designed space can reduce the barriers between online and onsite participants.

For students:

- Be mindful of your own role in interaction. Online students in particular may need to take more initiative to stay connected and visible.
- Communicate with your teacher if you're experiencing distance, emotional, cognitive, or otherwise. Teachers are often unaware unless this is explicitly mentioned.
- When possible, make use of any opportunities for cross-group interaction. Hybrid education works best when all participants are actively engaged.

These recommendations are grounded in multiple studies from this dissertation, highlighting that technology, facilitation of informal interaction, and deliberate planning are central to hybrid learning success. By combining these strategies, teachers, designers, and students can create hybrid environments that are equitable, engaging, and effective.

6.4   Strengths and limitations

As with any research project, this dissertation has both strengths and limitations that are important to reflect on. Acknowledging these helps to better understand the scope of the findings and the context in which they should be interpreted. One strength of this dissertation is that it brings together multiple perspectives on hybrid education. Rather than focusing on just one group or course, the studies included in this work examined the views and experiences of students, teachers, and course designers across different settings. This allowed for a more complete and layered understanding of the challenges and opportunities within hybrid education. While this doesn't mean the findings are universally applicable, it does help to paint a broader picture of what hybrid education can look like in practice. Another strength is the way each study is grounded in both theory and practical experience. Theoretical frameworks like Moore's TD theory helped to shape the research questions and interpretation of results, but the studies were also closely connected to real courses, real people, and real challenges. This helped keep the work relevant to what is actually happening in educational settings, rather than staying purely abstract.

At the same time, there are several limitations to keep in mind. One of the most important is that all four studies included relatively small sample sizes. This is understandable, given the qualitative and context-specific nature of the research, but it does limit the generalizability of the findings. The results should therefore be seen as exploratory and indicative, rather than conclusive. A related limitation is that the experiences of online students, while included, may still be underrepresented. Especially in hybrid settings,

online students are often less visible, both in the classroom and in research. Although their perspectives were explicitly sought, it is possible that certain aspects of their experience remain less well captured. Additionally, while the inclusion of multiple perspectives is a strength, it also brings variation in terms of context and focus. The studies were conducted within one institution, and each focused on different types of courses or programs. This means that although some broader patterns could be identified, the findings are still shaped by the specific conditions of the cases studied. Lastly, it is worth noting that hybrid education continues to develop. This research took place in the years following the COVID-19 pandemic, a time of rapid change and adaptation. As institutions, technologies, and student expectations continue to shift, the challenges and solutions identified here may also evolve.

Overall, the aim of this dissertation was never to offer definitive answers, but rather to explore how hybrid education is experienced and designed in real-life settings. The hope is that these insights can serve as a useful starting point for further thinking, discussion, and research.

6.5   General discussion

Hybrid education is often presented as a win-win format, offering both flexibility and inclusivity. However, the findings across all four studies suggest that this assumption does not always hold true. While hybrid formats can indeed be valuable, especially in times of crisis or for students with specific needs, they also bring with them a distinct set of challenges that should not be overlooked. One of the most important takeaways from this dissertation is that hybrid education is not yet equivalent to traditional onsite education in terms of experience or outcome. This is particularly evident when looking at the differences between onsite and online students in their opportunities for interaction, their levels of engagement, and their overall sense of inclusion. While technology allows students to be "present" from a distance, presence alone is not the same as participation or connection. As the results have shown, being connected does not always mean being included.

At the same time, there are clear cases in which hybrid education is not just a necessity but the best available solution. Students dealing with illness, caregiving responsibilities, housing shortages, or long commutes often rely on hybrid options to continue their studies. The fact that these students still want to participate in education is something that should be rewarded. In these instances, hybrid education is not just about convenience, it is about access. The key question then becomes: how can we ensure that

students who are online are offered an experience that is not only parallel, but also equitable? What I find incredibly important is that these students who cannot go to the lesson but still want to participate are given equal learning opportunities as students who can be present in the classroom. Important to note is that even though it is the teacher's responsibility to provide these students with an equal learning opportunity, it is the students' responsibility to grab these opportunities that they are given.

This is where the notion of TD becomes especially relevant. Across the studies, it became clear that online students are more prone to experiencing psychological and emotional distance, even when physically "present" via video. This should not be interpreted as a lack of motivation or effort on their part. On the contrary, the willingness of these students to participate despite challenging circumstances deserves recognition. The burden of adjustment should not fall solely on them. Instead, the responsibility lies with institutions and educators to design hybrid environments in which the experience of being online is not inherently second-best. In reflecting on these experiences, social presence research provides a complementary lens. Even when students are visible on video, their perceived psychological closeness, emotional safety, and interpersonal awareness significantly influence engagement and learning satisfaction (Kreijns et al., 2024; Richardson, Maeda, Lv, & Caskurlu, 2017). Our findings echo this: informal interactions, casual check-ins, and brief peer conversations, moments that often happen naturally onsite, are essential for reducing feelings of disconnection. These interactions highlight the socio-emotional layer of engagement that TD alone does not fully capture. They show how trust, recognition, and relational cues support cognitive and behavioral engagement, particularly for online students who might otherwise feel peripheral. Online students frequently reported missing these relational cues, which led to lower engagement and participation. Linking this to social presence helps explain why being "connected" does not automatically translate into being included; engagement is not only a structural or cognitive phenomenon but also a socio-emotional one.

This dissertation also raises broader questions about how we think about interaction and engagement in education. Do we truly understand what it means to feel involved, to be heard, and to matter in a classroom that spans both physical and digital space? The studies also show that problems that teachers run into when teaching in a hybrid manner or not that different than problems they run into when teaching in a traditional classroom. I personally see that teachers who find it difficult to create student

engagement in a traditional classroom find this even harder when teaching in a hybrid manner. So as hybrid formats become more embedded in educational practices these things are important to keep in mind. Looking forward, future research should deepen our understanding in several key areas. Firstly, there is a need to explore how the affordances of hybrid educational technologies, ranging from synchronous video platforms to collaborative digital tools, can be optimized not only for formal learning but also for informal, spontaneous interactions that sustain cognitive and social engagement. Innovations such as spatial audio or virtual breakout rooms hold promise in better replicating physical classroom dynamics and deserve further investigation. Secondly, professional development for educators is essential to navigate the multifaceted demands of hybrid teaching. Effective training must address not only technical skills but also pedagogical strategies for managing TD, facilitating inclusive and dialogic learning, and balancing the affective and cognitive needs of diverse learners within hybrid settings. Such support will empower educators to move from feeling overwhelmed by hybrid complexity to confidently orchestrating rich, equitable learning experiences. Thirdly, while TD theory provides a valuable lens for understanding hybrid education challenges, it requires evolution to more fully capture the relational, emotional, and socio-cultural complexities of post-digital learning environments. Future theoretical work should expand this framework to incorporate dimensions such as emotional engagement, power relations, and cultural diversity, thereby better guiding research and practice in increasingly hybrid and interconnected educational contexts. By synthesizing empirical findings from diverse educational contexts, theoretical exploration, and practical insights, this dissertation offers a grounded, multifaceted contribution to the evolving landscape of hybrid higher education. It calls on educators, researchers, and institutions to move beyond reactive emergency adaptations toward proactive, reflective design that centers human connection and equity. Only through such deliberate, intentional hybridity can the transformative potential of hybrid education be realized, paving the way for more accessible, inclusive, and meaningful learning experiences in a rapidly changing world.

In short, hybrid education is here to stay. But if we want it to be more than a stopgap or compromise, we must be willing to ask difficult questions and make deliberate choices. This dissertation is a small step in that direction.

6.6   Conclusion

This dissertation set out to explore the practical challenges of hybrid education, with a particular focus on the role of TD and how it affects

interaction, engagement, and learning experiences for both online and onsite students. Across the four studies, we examined these challenges from different perspectives and contexts, providing a nuanced view of what happens when hybrid education is implemented in real classrooms. The findings suggest that hybrid education is not inherently the most effective or desirable form of teaching. It is not a one-size-fits-all solution and should not automatically replace traditional or fully online formats. Instead, hybrid education can be especially valuable in specific situations, such as when students are unable to attend classes due to illness, caregiving responsibilities, or geographical distance, or in cross-border initiatives like COIL education. In these cases, it offers a way to maintain participation and engagement. However, even in such scenarios, simply offering a hybrid option is not enough. When hybrid education is chosen, it needs to be thoughtfully designed and carefully executed. Both online and onsite students deserve equal access to a high-quality learning experience. If this is not ensured, hybrid education risks becoming a second-best option for those who are already facing barriers. The overarching message of this discussion, then, is not that hybrid education should be widely adopted, but that it should be done well when it is adopted. The challenges it brings, particularly in terms of interaction and TD, are not insurmountable, but they require attention, design, and reflection. By taking this seriously, educators and institutions can move beyond emergency adaptations and toward meaningful, inclusive, and engaging hybrid learning environments

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Summary

In recent years, higher education institutions have been increasingly adopting hybrid formats, where online and onsite students participate simultaneously, as a flexible response to changing educational demands, globalization, and technological advancement. While hybrid education offers opportunities to broaden access and connect international learners, it also introduces new complexities, particularly in terms of student interaction, engagement, and the emotional and psychological dynamics that influence learning. One organizing principle behind these dynamics is transactional distance (TD), a theory originally developed for distance education. It encompasses the level of psychological distance students experience towards each other and/or their teachers. Despite the relevance of TD for hybrid education, the theory remains under-explored and under-adapted to the hybrid context, where students interact across in both the classroom and online environment synchronously. This dissertation explores the practical challenges that occur during hybrid education and how these challenges can be overcome. Moreover, we explored the role of TD in hybrid education and how it impacts interaction, engagement and learning experiences for both online and onsite students. Four separate studies examined the conditions that shape engagement and interaction, with a focus on both teachers' and students' experiences, and how hybrid formats influence participation, relational dynamics, and instructional design.

The first study (**Chapter 2**) investigates hybrid education during the COVID-19 pandemic from the teacher's perspective. The study showed a tension that teachers experience while teaching in a hybrid manner. Not only are they teaching, they are also moderating the online environment, working on technical problems and have two very distinct groups to focus on. Teachers had a hard time dividing their attention between the two groups, often leaving the online students feeling neglected. Moreover, the teachers also reported feeling a greater distance between them and the online students, compared to them and the onsite students. This study gave us a baseline of experiences and showed us some of the strengths and weaknesses of hybrid education.

Building upon these findings, the second study (**Chapter 3**) shifts focus to both the students' and the teachers' experiences. We explored the TD experienced by both the online and onsite students during the lessons and classroom discussions within a small history of science course. We noticed

that online students need more propping to participate in the discussions and according to the onsite students are often not even seen as "real students". This study showed us that even though the teacher encouraged the online students to participate in the discussion, the participation always remained at a surface level. According to both the students and teachers this might be due to the lack of informal interaction the online students had. These interaction, which the online students did not have, created a feeling of connectivity and thus made it easier to participate in the discussions.

The third study (**Chapter 4**) provides a systematic review of the existing literature on TD within hybrid education. It finds that while TD is often cited as a relevant framework, few studies actually use the concepts in light of hybrid education. Most studies use TD as a background theory rather than adapting its constructs, dialogue, structure, and autonomy, to the hybrid context. Notably, the review identifies lesson design and pre-structured interaction as key elements in reducing TD. Contrary to traditional online learning literature that promotes flexibility as a value, this study argues for intentional pre-planning to ensure equitable interaction across modalities. When interaction is left to chance, online students are disproportionately excluded, exacerbating the psychological and communicative gaps that TD seeks to explain.

The fourth and final study (**Chapter 5**) focuses on international hybrid learning through a Collaborative Online International Learning (COIL) course involving 120 students and teachers from the Netherlands and the UK. This study uses a mixed-methods approach to explore how TD emerges in both fully online and hybrid sessions. It finds that, hybrid sessions allow for spontaneous small talk and informal moments, which play a critical role in building rapport and fostering authentic engagement In contrast, fully online sessions, although equalizing in access, tend to feel more formal and disengaging, with limited informal interaction and increased psychological distance. However, technical difficulties and variable attendance of remote participants still undermined overall cohesion. The study concludes that informal social interaction, along with robust technology and deliberate instructional design, are essential for effective hybrid international collaboration.

Across all four studies, one central finding emerges: hybrid education demands a rethinking of interaction and presence that accounts for the uneven affordances of physical and digital spaces. TD theory, while still useful, requires adaptation to account for the simultaneity and asymmetry of hybrid

modalities. In contrast to traditional distance education, hybrid education introduces co-present inequities, where students share a class temporally but not experientially. This dissertation contributes to the field of educational research in several ways:

- Theoretical advancement: It refines the theory of TD to better fit hybrid contexts, highlighting the need to reconceptualize dialogue, structure, and autonomy in multimodal learning environments.
- Pedagogical implications: It underscores the importance of structured lesson design, pre-planned interactions, and the deliberate inclusion of informal communication opportunities to reduce distance and promote equity.
- Teacher perspective: It brings forward the often-overlooked emotional labor and identity fragmentation of hybrid teaching.
- International collaboration: It reveals the unique dynamics of international hybrid learning, where sociocultural differences compound the effects of modality, making informal interaction even more vital.

This research set out to explore the practical challenges of hybrid education, with a particular focus on the role of TD and how it affects interaction, engagement, and learning experiences for both online and onsite students. Across the four studies, these challenges were examined from different perspectives and contexts, providing a nuanced and grounded view of what occurs when hybrid education is implemented in real classroom settings. The findings suggest that hybrid education is not inherently the most effective or desirable form of teaching. It is not a one-size-fits-all solution and should not automatically replace traditional face-to-face or fully online formats. Instead, hybrid education can be especially valuable in specific situations, such as when students are unable to attend classes due to illness, caregiving responsibilities, or geographical distance, or in cross-border initiatives like COIL. In these contexts, it offers an important means to maintain participation and engagement, ensuring continuity of learning and connection. However, even in such scenarios, simply offering a hybrid option is not enough. When hybrid education is chosen, it requires intentional, thoughtful design and careful execution. Both online and onsite students deserve equal access to a high-quality, inclusive learning experience. Without this commitment, hybrid education risks becoming a second-best alternative for those who already face barriers, potentially exacerbating inequities rather than mitigating them.

Summary

The overarching message of this dissertation, therefore, is not that hybrid education should be widely adopted indiscriminately, but rather that when it is adopted, it must be done well. The challenges it brings, particularly those relating to interaction and TD, are significant but not insurmountable. They demand ongoing attention, deliberate design, and critical reflection from educators and institutions alike. If hybrid education is here to stay, its promise of inclusivity and flexibility can only be fully realized through such intentionality. Recognizing hybrid learning environments as complex relational spaces, educators must actively manage TD, designing opportunities for dialogue and informal interactions that build trust, social presence, and a sense of belonging for all participants.

Samenvatting

In de afgelopen jaren maakt het hoger onderwijs steeds vaker gebruik van hybride onderwijsvormen, waarbij online en fysieke studenten gelijktijdig deelnemen. Deze vorm biedt een flexibele reactie op veranderende onderwijsbehoeften, globalisering en technologische vooruitgang. Hoewel hybride onderwijs kansen biedt om de toegankelijkheid te vergroten en internationale studenten met elkaar te verbinden, brengt het ook nieuwe uitdagingen met zich mee, met name op het gebied van interactie, betrokkenheid en de emotionele en psychologische dynamieken die leren beïnvloeden. Een theoretische lens om deze dynamieken te vatten is 'transactional distance' (TD), een theorie die oorspronkelijk is ontwikkeld voor afstandsonderwijs. TD beschrijft de mate van psychologische afstand die studenten ervaren ten opzichte van elkaar en/of hun docenten. Ondanks de relevantie van TD voor hybride onderwijs, is de theorie nog nauwelijks onderzocht of aangepast aan de hybride context, waarin studenten gelijktijdig in de klas en online participeren. Dit proefschrift onderzoekt de praktische uitdagingen die zich voordoen bij hybride onderwijs en hoe kunnen worden aangepakt. Daarnaast wordt verkend welke rol TD in hybride onderwijs heeft, en hoe TD van invloed is op interactie, betrokkenheid en leerervaringen van zowel online als fysieke studenten. In vier studies werd onderzocht hoe betrokkenheid en interactie kunnen worden vormgegeven, met aandacht voor de ervaringen van zowel docenten als studenten, en hoe hybride formats participatie, relationele dynamieken en onderwijsontwerp beïnvloeden.

De eerste studie (**Hoofdstuk 2**) betreft hybride onderwijs tijdens de COVID-19-pandemie vanuit het perspectief van docenten. Hieruit bleek het spanningsveld dat de docenten ervaren: ze geven les, modereren tegelijkertijd de online omgeving, lossen technische problemen op én moeten hun aandacht verdelen over twee duidelijk verschillende groepen. Dit leidde ertoe dat online studenten zich vaak verwaarloosd voelden. Daarnaast gaven docenten aan een grotere afstand te ervaren tot online studenten dan tot fysieke studenten. Deze studie vormde een belangrijke basis en bracht sterke en zwakke punten van hybride onderwijs in kaart.

De tweede studie (**Hoofdstuk 3**) richt zich op zowel student- als docentervaringen. In deze studie werd onderzocht hoe zowel online als fysieke studenten TD ervoeren tijdens lessen en klassikale discussies in een kleine mastercursus over wetenschapsgeschiedenis. Online studenten bleken meer stimulans nodig te hebben om deel te nemen aan discussies en werden

door fysieke studenten vaak niet als 'echte' studenten gezien. Ondanks aanmoediging van de docent bleef de participatie van online studenten oppervlakkig, mogelijk door het ontbreken van informele interacties. Deze informele contacten, waar online studenten geen toegang toe hadden, droegen bij aan verbondenheid en maakten deelname aan discussies makkelijker.

De derde studie (**Hoofdstuk 4**) presenteert een systematische literatuurstudie naar TD in hybride onderwijs. Hoewel TD vaak wordt genoemd als relevant kader, gebruiken weinig studies TD als de theoretische lens, waarbij ze de kernconcepten, dialoog, structuur en autonomie, in de hybride context onderzoeken. De review identificeert lesontwerp en vooraf gestructureerde interactie als sleutel tot het reduceren van TD. In tegenstelling tot de traditionele online onderwijs-literatuur, die flexibiliteit als kernwaarde benadrukt, blijkt dat doelbewuste voorplanning om gelijke interactie te waarborgen in hybride situaties essentieel is. Wanneer interactie aan toeval wordt overgelaten, dan worden online studenten vaker buitengesloten, waardoor de psychologische en emotionele afstand (TD) toeneemt.

De vierde en laatste studie (**Hoofdstuk 5**) richt zich op internationaal hybride onderwijs via een Collaborative Online International Learning (COIL)-cursus met 120 studenten en docenten uit Nederland en het Verenigd Koninkrijk. Hier werd onderzocht hoe TD zich verhoudt tussen hybride sessies en volledig online sessies. De bevindingen laten zien dat hybride sessies ruimte bieden voor spontane gesprekken en informele momenten, die cruciaal zijn voor het opbouwen van vertrouwen en authentieke betrokkenheid. Volledig online sessies zijn daarentegen formeler, minder boeiend en kennen minder informele interactie, wat de psychologische afstand vergroot. Toch bleken technische problemen en wisselende aanwezigheid van online deelnemers ook in hybride settings de cohesie te ondermijnen. De studie concludeert dat informele sociale interactie, robuuste technologie en doelgericht lesontwerp essentieel zijn voor effectieve hybride internationale samenwerking.

Uit de vier studies komt een centrale conclusie naar voren: hybride onderwijs vereist een herziening van hoe interactie en aanwezigheid worden vormgegeven, rekening houdend met de ongelijke mogelijkheden van fysieke en digitale leeromgevingen. TD-theorie blijft bruikbaar, maar moet worden aangepast aan specifieke complexiteit van het hybride onderwijs. In tegenstelling tot traditioneel afstandsonderwijs creëert hybride onderwijs

ongelijkheden binnen gedeelde aanwezigheid, waarbij studenten wel gelijktijdig les volgen, maar uiteenlopende leerervaringen hebben. Dit proefschrift draagt op meerdere manieren bij aan het onderwijsonderzoek:

- Theoretische bijdrage: verfijnt de TD-theorie voor hybride contexten, met nadruk op het herdefiniëren van dialoog, structuur en autonomie in multimodale leeromgevingen.
- Pedagogische implicaties: benadrukt het belang van gestructureerd lesontwerp, vooraf geplande interacties en het doelbewust creëren van informele communicatiemomenten om afstand te verkleinen en gelijkwaardigheid te bevorderen.
- Perspectief van de docent: belicht de vaak onderbelichte emotionele belasting en identiteitsfragmentatie van docenten die hybride lesgeven.
- Internationale samenwerking: laat de unieke dynamiek zien van internationaal hybride onderwijs, waarbij socioculturele verschillen de effecten van modaliteit versterken en informele interactie nog belangrijker maken.

Dit promotieonderzoek had tot doel de praktische uitdagingen van hybride onderwijs te verkennen, met bijzondere aandacht voor de rol van TD en de effecten op interactie, betrokkenheid en leerervaringen van zowel online als fysiek aanwezige studenten. De studies bieden een genuanceerd beeld van wat er gebeurt wanneer hybride onderwijs in de praktijk wordt toegepast. De bevindingen suggereren dat hybride onderwijs niet per definitie de meest effectieve of wenselijke vorm van lesgeven is. Het is geen universele oplossing en kan traditionele of volledig online formats niet zonder meer vervangen. Het kan echter zeer waardevol zijn in specifieke situaties, zoals bij ziekte, mantelzorg, geografische afstand, of in internationale initiatieven zoals COIL-onderwijs. In deze contexten kan hybride onderwijs deelname en betrokkenheid in stand houden en continuïteit in leren en verbinding waarborgen. Toch is het aanbieden van een hybride optie alleen niet voldoende. Wanneer voor hybride onderwijs wordt gekozen, vereist dit een bewuste, doordachte en zorgvuldige uitvoering. Gebeurd dit niet, dan is er het risico dat hybride onderwijs een tweederangs alternatief wordt voor studenten.

De kernboodschap van dit proefschrift is dat hybride onderwijs alleen effectief kan zijn wanneer het met intentie wordt vormgegeven. De uitdagingen, met name rond interactie en TD, zijn aanzienlijk maar overkomelijk, mits er voortdurend aandacht voor is en er doelgericht

ontwerp en kritische reflectie plaatsvindt. Om hybride onderwijs met de beloften van inclusiviteit en flexibiliteit tot bloei te laten komen moet het bewust en doordacht worden vormgegeven. Dit proefschrift pleit voor een dergelijke intentionele hybriditeit, niet als technische oplossing, maar als pedagogische inzet voor gelijkwaardige betrokkenheid, duurzame aanwezigheid en het bevorderen van doordachte dialoog over fysieke en virtuele grenzen heen.

Curriculum Vitae

Veerle Ottenheim was born on 28 February 1997 in The Hague, the Netherlands. She completed her secondary education at the Haags Montessori Lyceum, after which she studied Biology and Medical Laboratory Research with a specialisation in Infectious Diseases and Animal-Based Research at the University of Applied Sciences Leiden (Hogeschool Leiden). During her bachelor's degree, she participated in the Honours Programme, where she engaged in projects with societal relevance that extended beyond the laboratory. After completing both her bachelor's degree and the honours programme, she obtained her Master's degree in Nutrition and Health with a specialisation in Molecular Nutrition at Wageningen University & Research.

Throughout both her bachelor's and master's studies, Veerle developed a strong interest in education. She designed and taught a course for the PABO at Hogeschool Leiden and worked as a teaching assistant at Wageningen University. When the COVID-19 pandemic began during her master's, she contributed to redesigning several courses in the Nutrition and Health programme to fit the new hybrid and online learning context. During this period, she also published her first scientific paper on the effects of pro- and prebiotics on muscle wasting during cancer. This experience sparked her enthusiasm for research and inspired her to pursue a PhD.

In 2021, Veerle started as a PhD candidate at the Freudenthal Institute, Utrecht University. This marked a shift from molecular research to educational research, focusing on scientific discussion and argumentation in hybrid higher STEM education—where teachers and students interact both online and on campus simultaneously. Her research included interview studies, case studies, literature reviews, and conversation analyses, involving both teachers and students as active participants. She presented her work at several (inter)national conferences and was invited to speak at educational institutions exploring hybrid learning environments.

During her PhD, Veerle also taught at the Freudenthal Institute, served on the departmental PhD advisory committee, and helped organize research meetings and PhD retreats. In addition, since 2022 she has been volunteering at her local library, where she supports children from diverse socio-economic backgrounds with their homework and helps them navigate the educational system.

Dankwoord

Het klinkt misschien suf, maar ik ga mijn dankwoord gebruiken om mensen te bedanken. In de afgelopen vier jaar heb ik namelijk flink wat mensen om mij heen verzameld die ik mag bedanken voor hun support in deze periode.

In september 2021 begon ik met mijn promotieonderzoek bij het Freudenthal Instituut (FI). Het was een rare tijd, want we waren wel uit een lockdown, maar echt normaal was alles niet. Ik heb dan ook de meeste collega's leren kennen met een mondkapje op. De eerste twee maanden van mijn werk op het FI waren ontzettend eenzaam en, heel eerlijk, totaal niet leuk. Ik had ontzettend last van imposter-syndroom, want wat deed ik als biomedisch onderzoeker nou bij een onderwijsinstituut? Daarnaast was ik ook ongeveer de enige van mijn leeftijd (sorry Ralph en Paul). In die maanden was Hang de enige met wie ik echt kon praten. So thank you Hang for being there for me in those first two months. It's insane to think that we started around the same time, worked through Covid regulations and now you are a doctor and I am hopefully about to become one.

Na die eerste twee maanden waarin ik amper collega's ontmoette, was daar de heidag. Wat ik daar precies deed weet ik nog steeds niet, maar dit was wel het eerste keerpunt in mijn promotietraject. Op deze hei-dag waren er ineens heel veel collega's, ze bestonden dus echt. Hier ontmoette ik Elske en Lisa, en een week later ook Aike. Ik ben daar ontzettend dankbaar voor, want dat eerste jaar van mijn promotietraject waren jullie alledrie echt steunpilaren voor mij. Na het eerste jaar was daar ook Marieke, die zich snel bij ons groepje, jonge vrouwelijke PhD's die van bier houden, voegde en met wie ik een jaar lang de research meetings heb mogen organiseren. Niet alleen hebben we ontzettend veel lol op kantoor gehad, maar ook daarbuiten, en onze bieruitjes zal ik altijd met veel plezier herinneren.

Nu zijn Aike en Lisa ook mijn twee geweldige en lieve paranimfen, dus ik wil graag nog even verder toelichten hoe bijzonder deze twee zijn. Hoewel we elkaar pas vier jaar kennen, wat eigenlijk best lang is, zijn jullie niet alleen onderdeel van mijn favoriete collega's, maar ook twee van mijn beste vriendinnen geworden. Ik denk dat er weinig mensen zijn die mij in de afgelopen vier jaar zoveel hebben zien huilen als jullie, en dat zegt wel iets. Ik schrijf dit nu drie weken nadat ik weg ben bij het FI, en dat voelt raar. Het is vreemd om jullie niet elke dag te zien, het is raar dat ik Aike niet meer kan afleiden tijdens het werk of zo hard om haar kan lachen dat ik van mijn stoel afval. Het is vreemd dat ik niet meer kan aankloppen bij Lisa in haar kantoor, neerploffen op de bank, een theetje kan drinken en kan klagen over wat er nu weer allemaal fout ging. Gelukkig betekent geen collega's meer zijn niet

dat we geen vrienden meer zijn, en zie ik jullie, net zoals hiervoor, ook gewoon buiten het werk. Toch mis ik het om samen met jullie te werken, want ik kan jullie beide vertellen dat jullie een groot onderdeel van mijn werkplezier waren. Jullie maakten het werk altijd leuker en ik heb in de afgelopen vier jaar zo ontzettend veel van jullie mogen leren. Dus ik wil jullie graag bedanken voor het feit dat jullie zulke ontzettend mooie mensen zijn.

Ik vond connecties maken met mijn collega's ontzettend belangrijk. Dit zorgt bij het schrijven van een dankwoord wel voor wat problemen, er zijn namelijk zoveel mensen die ik kan bedanken. Dus ik splits het op in wat groepen zodat het hopelijk geen pure chaos wordt.

Lieve kamergenoten van 3.71, ik weet niet wat ik de afgelopen vier jaar zonder jullie had gemoeten. Het was ontzettend prettig om altijd een klankbord te hebben en iemand om mee te kunnen praten wanneer dat nodig was. Het klagen over supervisors, de vele theepauzes, het verhuizen en het opnieuw inrichten van ons kantoor, dat zijn allemaal dingen waar ik met plezier op terugkijk. Nu zaten er heel veel mensen in kantoor 3.71 de afgelopen jaren, dus de volgende mensen wil ik in het bijzonder bedanken: natuurlijk Aike, Joost, Elian en Simone. Dank jullie wel.

Lieve HPS'ers, dank jullie wel voor het onofficieel adopteren van mij in de HPS-groep. Hoewel ik zelf al in twee onderzoeksgroepen zat, was ik heel blij dat ik ook onofficieel geadopteerd was in jullie groep. Het was mij een waar genoegen om bijna al mijn lunchpauzes met jullie te spenderen en zo ook heel veel nieuwe random informatie te leren. Ik wil specifiek Hieke bedanken voor al haar ontzettend goede advies en voor het feit dat ze mij altijd serieus heeft genomen. Ook wil ik graag Niels bedanken voor al zijn boekenaanbevelingen, het altijd vergeten dat ik niet echt in de HPS-groep zat en zijn humor. Dan zijn er natuurlijk ook de promovendi van HPS, Lisa, Elske en Marieke, die ik nogmaals wil bedanken.

Lieve SEC-collega's, ook jullie wil ik bedanken aangezien ik wel officieel onderdeel was van jullie onderzoeksgroep. Ik wil jullie bedanken voor alles wat ik van jullie heb mogen leren. In het bijzonder wil ik Michiel van Harskamp bedanken voor het zijn van een geweldige collega. Dankjewel voor al je humor de afgelopen jaren en voor het zijn van een geweldig voorbeeld. Verder wil ik ook graag Koos bedanken voor zijn humor en het zijn van een klankbord als ik irritante studenten begeleidde. Zowel de science-collega's als de communicatiecollega's, jullie zijn geweldig en dank jullie wel.

Lieve wiskunde-collega's, hoewel ik ook officieel onderdeel was van de wiskundegroep, was dit de groep waarin ik het minst aanwezig was. Toch heb ik veel mogen leren van mijn wiskundige collega's. Jacoliene, dankjewel voor

al je gezelligheid. Christos, thank you for all your banter and cat pictures over the last couple of years. Michiel Doorman, dankjewel voor het altijd luisteren naar mijn opmerkingen over promotietrajecten en het serieus nemen van al mijn suggesties en meningen.

Dan mijn promotoren, Paul en Ralph. Zoals ik al eerder zei had ik in het begin werkelijk geen idee waarom ik aangenomen was en wat ik op het FI deed. Zoals jullie ook weten verliepen de eerste anderhalf jaar nogal stroef, maar mede dankzij jullie begeleiding en jullie vertrouwen in mij is dit hierna veranderd. Jullie hebben ervoor gezorgd dat ik een betere onderzoeker ben geworden en geen moeite meer heb met het zeggen dat jullie het verkeerd hebben en ik toch echt gelijk heb. Paul, ik weet dat ik voor jou, zeker in het begin, even wennen was, waar Ralph en ik vaak één chaotische hersencel deelden, was jij altijd de rust zelve. Ik wil je daarvoor ook bedanken, want ik weet zeker dat ik door jouw rust en gestructureerdheid, als het aankomt op schrijven en onderzoek, ook zeker een betere onderzoeker ben geworden. Ralph, zoals ik al zei matchten wij vanaf het begin als het aankwam op de levels van energie en onze manier van werken. Ik heb zo ontzettend veel van je geleerd dat het moeilijk is om te omschrijven wat ik nou allemaal heb geleerd. Onze samenwerking heb ik altijd als heel fijn ervaren en ik vond het heel erg fijn dat ik voor alles altijd bij jou terecht kon. Dank jullie wel.

Nu zijn niet alleen al mijn collega's ontzettend belangrijk geweest tijdens mijn promotietraject, ook mijn vrienden en familie hebben hier een grote rol in gespeeld.

Als eerste mijn familie. Lieve Tara, Muriel, papa en mama, dank jullie wel voor het feit dat jullie mij altijd hebben gesupport, niet alleen tijdens mijn promotietraject maar mijn hele leven. Ik weet oprecht niet wat ik zonder jullie had moeten doen. Ik wil mijn zusje Tara bedanken voor haar humor en spontaniteit, wat ervoor heeft gezorgd dat ik niet alles zo ontzettend serieus neem, wat mijn promotietraject een stuk aangenamer heeft gemaakt. Muriel, dankjewel voor zo'n geweldige nicht zijn, voor mij opvangen wanneer het nodig is en mij af en toe out of the box te laten denken. Dan wil ik mijn vader nog extra bedanken voor het promoten van mijn onderzoek op congressen waar hij heen gaat en het feit dat hij de afgelopen vier jaar een geweldig klankbord voor mij is geweest. Daarnaast wil ik mijn moeder ontzettend bedanken voor al haar support en feedback, waar ik bij mijn vader terecht kan voor onderzoek en onderwijs, kan ik bij mijn moeder terecht voor al het andere wat gerelateerd is aan werknemer en mens zijn, en daar ben ik zo ontzettend dankbaar voor. Daarnaast wil ik mijn moeder graag bedanken voor het feit dat zij heeft doorgezet bij juf Ineke (groep 5), die aanvankelijk zei dat ik, als ik heel erg mijn best deed, misschien naar de mavo kon. Dankzij

het doorzetten van mijn moeder kreeg ik de kans op meer uitdaging, en kijk waar ik nu sta: mijn proefschrift verdedigend! Al jullie goede advies heeft mij zoveel vertrouwen en zelfverzekerdheid gegeven. Heel erg bedankt daarvoor.

Dan mijn lieve vrienden. Dank jullie wel voor het luisteren naar al mijn onderzoek- en onderwijspraat, waarvan jullie de helft van de tijd vast niks begrepen, maar wat jullie toch serieus namen. Lieve Amina, Anne, Annemijn, Kirsten, Samantha en Verena, dank jullie wel voor het er zijn voor mij en voor al jullie advies in deze periode, en natuurlijk voor onze weekendjes weg, die altijd aan het begin van het schooljaar zijn en die zorgden voor een kleine ontsnapping aan de post-vakantiedrukte op de uni. Lieve Willemijn, dankjewel voor al je humor, je luisterende oor en al onze therapiesessies die wij altijd in de boot hebben. Onze bootspraak heeft mij altijd veel goed gedaan en daar wil ik je heel erg voor bedanken. Lieve Moniek en Jesse, ook jullie wil ik heel graag bedanken voor jullie support en jullie humor, ik koester onze tripjes naar Londen ontzettend erg en ook deze mini-vakanties hebben mij ontzettend geholpen met het minder gestrest zijn. Lieve Maud, hoewel je helemaal in de verre VS zit, ben jij toch een geweldige steunpilaar voor mij geweest de afgelopen jaren. Dankjewel voor het altijd naar mij luisteren en je nuchtere, directe mening. Lieve Divanie, Olivier en Wiesje, ook jullie wil ik bedanken voor het feit dat jullie er altijd voor mij zijn en al jullie goede advies. Eerlijk gezegd weet ik niet hoe ik de afgelopen vier jaar had overleefd zonder jullie. Dan wil ik nog een vriend specifiek in het zonnetje zetten, en dat is Olivier. Ik denk dat Olivier, naast Lisa en Aike, mij het meest door deze PhD heeft heen gesleept. Niet alleen hebben onze outdoorsy vakanties mij altijd erg goed gedaan, je was ook een groot onderdeel van mijn anti-burn-outplan het afgelopen jaar. Je was mijn wandelmaatje, mijn klankbord en heel vaak het luisterend oor dat ik nodig had. Daarnaast heb je mij vaak genoeg een spiegel voorgehouden, altijd met een frisse blik naar problemen gekeken en geef je ook nog eens ontzettend goed advies. Dus Olivier, dankjewel.

Nu wil ik dus nogmaals al mijn vrienden en familie bedanken voor hun steun en toeverlaat tijdens de afgelopen vier jaar. Zonder jullie had ik hier nu niet gestaan. Dus DANKJEWEL.

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Hybrid education, where online and onsite students learn together simultaneously, is increasingly adopted in higher education as a flexible response to changing educational needs and technological possibilities. It offers new opportunities for inclusion and international collaboration, yet also brings challenges related to interaction, engagement, and presence. This dissertation examines these challenges through the lens of transactional distance (TD), a theory describing the psychological and communicative gaps between learners and teachers.

Drawing on multiple empirical studies, this research explores how hybrid learning shapes experiences of connection and participation for both teachers and students. It investigates how TD manifests in classroom practices, how it can be reduced through intentional lesson design and structured interaction, and how informal communication supports social presence and engagement, particularly in international and cross-cultural contexts.

The findings show that hybrid education is not a one-size-fits-all solution but a complex relational space that requires deliberate and thoughtful design. When implemented with care, it can foster inclusion and meaningful connection across modalities. Without such attention, however, it risks reinforcing existing inequities. This dissertation offers theoretical, pedagogical, and practical insights for educators and institutions seeking to enhance engagement and equity in hybrid learning environments.