Teachers' Learning Processes in Interdisciplinary University Education

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Abstract

This study aims to understand how learning mechanisms occur when teachers collaborate with teachers from other disciplines in interdisciplinary education. Types of learning mechanisms include identification, coordination, reflection and transformation. These mechanisms represent the learning potential when crossing disciplinary boundaries. Although previous studies show that teachers who collaborate in interdisciplinary education face challenges, they pay little attention to the teachers' learning opportunities. To that end, twelve interviews with teachers at Utrecht University (UU) were conducted for this study. A qualitative design with a narrative approach using semi-structured interviews was used to identify the four learning mechanisms. First, the results demonstrate that identification occurs in assessing students, differences in teaching and hierarchy. Second, coordination takes place in social interaction, common themes and the organisation of interdisciplinary education. Third, reflection results in creating a new perspective and gaining insight into one's own identity. Finally, transformation occurs by creating new educational practices and changes in interdisciplinary courses. The results emphasise the importance of maintaining a dialogue with teachers who contribute to interdisciplinary education because it provides insight into how they move across disciplinary boundaries.

Keywords: learning mechanisms, boundary crossing, interdisciplinary teacher collaboration, learning potential,

Challenges and Opportunities in Interdisciplinary Teacher Collaboration

Today's social, environmental, economic and philosophical issues and challenges are often so complex that it is difficult to fully understand them from one perspective (Jacob, 2015). Therefore, teachers train their students to deal with these complex challenges in higher education (Spelt et al., 2009). *Interdisciplinary education* aims to support the development of skills to cross disciplinary boundaries and integrate the knowledge of two or more disciplines to explain a phenomenon, solve a problem or raise a new question in a way that would have been impossible through a single discipline (Mansilla, 2006; Mansilla & Duraisingh, 2007; Hannon et al., 2018; Spelt et al., 2009). Interdisciplinary education starts from the idea that teachers can teach something they have not been trained in (I. van der Tuin, personal communication, January 12, 2022) and requires teachers to collaborate (Davis et al., 2015).

Interdisciplinary education, however, is also about crossing boundaries. Previous research on interdisciplinary teacher collaboration in higher education has identified several challenges for teachers (Hyland, 2006; Tiongson, 2018). For example, a case study by Hannon et al. (2018) examined teaching practices across disciplines within an Australian university. The authors found that existing institutional arrangements for curriculum coordination and administration were barriers to interdisciplinary teaching and the implementation of interdisciplinary education. Similarly, Goos and Bennison (2018) determined that institutional and cultural barriers that maintain disciplinary silos hinder interdisciplinary collaboration between teachers. This study explores the potential for learning for mathematicians and mathematics teachers at the boundaries between disciplinary communities at the university. Interdisciplinary education is challenging for teachers because it requires respect for the expertise of other colleagues from different disciplines (Hyland, 2006). Interdisciplinary education is also time-consuming and labour-intensive because teachers have to cross boundaries and immerse themselves in another discipline with which

they are unfamiliar (Tiongson, 2018). Furthermore, interdisciplinary education requires teachers to send information and act as facilitators, but teachers also need to feel comfortable doing so (I. van der Tuin, personal communication, January 12, 2022).

Regardless, working on interdisciplinary education provides learning opportunities for teachers, such as sharing subject knowledge across disciplinary boundaries, interweaving content from different disciplines and collaborating across disciplines, which can lead to professional development opportunities (Goos & Bennison, 2018; Pharo et al., 2012; Tiongson, 2018). In addition, interdisciplinary education positively impacts students' motivation (Tiongson, 2018). Therefore, understanding teachers' challenges and opportunities in interdisciplinary collaboration can strengthen interdisciplinary education for teachers and students.

Creating a deep understanding of how teacher learning can occur at the boundaries of the disciplines in which they collaborate on interdisciplinary education can help teachers learn new techniques and content (Craig, 2012). This study examines how individual learning mechanisms occur within teachers when they collaborate with teachers from other disciplines in interdisciplinary education. Therefore, it contributes to understanding teachers' challenges and opportunities in interdisciplinary teacher collaboration.

Challenges of Interdisciplinary Education

A case study by Lu (2020) examined the impact of interdisciplinary teacher collaboration on the professional development of five teachers. Working in engineering and business disciplines, these teachers designed, developed and implemented an English-medium instruction (EMI) course. The five teachers experienced interdisciplinary collaboration as challenging due to their lack of confidence, self-efficacy, language proficiency and pedagogical knowledge. However, the results also suggest that by sharing these challenges, teachers improved their instructional skills, gained new insights into their

teaching and were better able to facilitate student learning. While Pharo et al.'s (2014) study indicates that teachers could have insufficient knowledge about teaching practices and the curricula of other disciplines, Lu's research shows that sharing challenges improves teachers' delivery of disciplinary content.

Teachers' Learning in Interdisciplinary Education

Previous studies show that boundaries can lead to learning (e.g. Akkerman & Bakker, 2010; Akkerman & Bruining, 2016). Furthermore, *boundary crossing* describes how and when learning occurs at a discipline's boundaries (Akkerman & Bakker, 2011; Bronkhorst & Akkerman, 2016; Hazen et al., 2018). Therefore, boundary crossing is an appropriate theoretical lens to study the learning mechanisms of higher education teachers.

According to Wenger et al.'s (2002) theory of situated learning, boundaries offer opportunities for new insights and developments. This theory sees learning as an engaged form within a community of practice to emphasise collaborative effort in meaning-making (Lave & Wenger, 1991). Similarly, interdisciplinary education focuses on teamwork, supports knowledge integration and enhances collaborative skills while crossing boundaries (Klein, 2005; Lyall et al., 2015; Manathunga et al., 2006; Spelt, 2009). Teachers who work together are referred to as "communities of practice" and are bound by a practical goal to share their knowledge, passion, uncertainties and confusion (Sherer et al., 2003; Viskovic, 2006).

Learning can occur when teachers work together with teachers from other disciplines on interdisciplinary education. Akkerman and Bakker (2011) and Akkerman and Bruining (2016) identified four potential learning mechanisms when crossing boundaries: identification, coordination, reflection and transformation. These learning mechanisms can be seen as a dialogical process (Akkerman & Bakker, 2011; Ryymin & Lamberg, 2021) that is somehow interrelated. For example, identification and reflection focus on meaning-oriented

learning processes, whereas coordination and transformation emphasise practice-based learning processes (Akkerman & Bakker, 2011).

Identification refers to the two dialogical processes of othering and legitimising coexistence. *Othering* involves questioning the core identity of each practice and determining whether they are related, which provides insight into the practices (Akkerman & Bakker, 2011; Akkerman & Bruining, 2016; Ryymin & Lamberg, 2021). On the other hand, the process of *legitimating coexistence* explains how teachers who participate in different domains can follow each domain and be accepted by others in the various domains (Akkerman & Bakker, 2011; Bogenrieder & van Baalen, 2007). Therefore, the learning potential in the identification process focuses on making sense of different practices and related identities (Akkerman & Bakker, 2011).

Coordination is about finding effective means and procedures that enable different practices to cooperate efficiently in distributed work, even without consensus (Star, 2010). Coordination requires communication and translation between different practices or perspectives (Landa, 2007; Ryymin & Lamberg, 2021). Furthermore, coordination attempts to organise the activity as smoothly as possible and create reliable routines (Akkerman & Bakker, 2011). The learning potential in the coordination process focuses on creating communicative connections, translations, boundary permeability and routinisation (Akkerman & Bakker, 2011).

Reflection is about creating a new perspective on one's own practice in the light of another practice. Creating these new perspectives leads to learning something new about one's own practice through other practices (Ryymin & Lamberg, 2021). The learning potential in the reflection process focuses on creating a set of perspectives and a new identity system that informs future practices (Akkerman & Bakker, 2011).

Transformation refers to changes in practices and can result in the development of (new) in-between boundary practices through ongoing collaborative work (Akkerman & Bakker, 2011). These (new) practices can emerge because of differences among them, allowing integration to occur. The learning potential in the transformation process focuses on creating honest dialogue and collaboration between practices (Akkerman & Bakker, 2011; Engeström et al., 1995). Before examining the learning mechanisms themselves, explaining how to examine them is essential.

Teachers' Learning and the Learning Mechanisms

As previously indicated, four learning mechanisms can identify how teachers learn at the boundaries of the disciplines. This current study examines these learning mechanisms at the intrapersonal level (Akkerman & Bruining, 2016). The *intrapersonal level refers* to people who simultaneously participate in interwoven practices and literally traverse these practices, such as a teacher from a linguistics discipline teaching a law course with a minor in both law and linguistics (Akkerman & Bruining, 2016). At the intrapersonal level, identification refers to an internal process whereby teachers attempt to distinguish their roles in interwoven practices. For instance, this same teacher may differentiate their role as a linguistics teacher by teaching a linguistics course and a law course.

A teacher seeking procedures or tools, such as a syllabus, to align their participation in the interwoven practices is an example of coordination. Reflection can occur when a teacher creates a new perspective on their role as a linguistics teacher, perhaps teaching a linguistics course and a law course. Lastly, transformation can happen when a teacher develops a hybrid position and integrates their role as a linguistics teacher teaching a law course (Akkerman & Bruining, 2016; Bakx et al., 2016).

Several instruments can be used to explore the learning mechanisms at the boundaries of disciplines. For example, a case study by Akkerman and Bruining (2016) used semi-

structured interviews in a case study to investigate the learning mechanisms of school partnerships for professional development in higher education. Goos and Bennison (2018) also used semi-structured interviews and written annual reports. Similarly, the present study examines learning mechanisms using semi-structured interviews.

Teacher Collaboration on Interdisciplinary Education in Higher Education

Previous studies paid little attention to teachers' learning opportunities in interdisciplinary education and often focused on how teachers collaborated and experienced the interdisciplinary collaboration. A study by Chaovanapricha and Chaturongakul (2020) explored the roles of English teachers and subject teachers engaged in the collaborative process of interdisciplinary teaching in English for Specific Purposes (ESP) subjects at a Thai university in Bangkok. They investigated the benefits and drawbacks of implementing such collaborations. This study shows that English teachers and subject teachers collaborated well in teaching ESP subjects by following the stages of joint planning, implementation and evaluation. Teachers from both disciplines had mutual goals and agreed on specific course objectives. In addition, the English teachers gained confidence in their knowledge of the subject matter, and the subject teacher gained more awareness of the skills needed to teach English.

A case study by Pharo et al. (2012) evaluated teacher collaboration in implementing interdisciplinary sustainability programmes across four Australian universities. This study shows that teachers who teach together see this as an important addition to discussing theories and exchanging ideas about different areas within education. Nevertheless, teachers perceive workload as the biggest barrier to interdisciplinary education collaboration. In addition, teachers perceive interdisciplinary education as a logistical and administrative burden. In Pharo et al.'s study, a deployed network facilitator alleviated some of the logistical and administrative workloads, making it easier for teachers to collaborate in interdisciplinary

education. Therefore, Chaovanapricha and Chaturongakul (2020) and Pharo et al. (2012) show that teacher collaboration in interdisciplinary education offers benefits for higher education but poses challenges for teachers at the same time.

Purpose of the Present Study

Interdisciplinary education aims to integrate disciplinary knowledge to solve social issues (e.g. Mansilla, 2006; Jacob, 2015). Teachers have an important role in interdisciplinary education as they are expected to have interdisciplinary expertise, collaborate across disciplines and thus guide students to integrate knowledge from different disciplines (e.g. Davis et al., 2015; Spelt et al., 2009). The boundary-crossing perspective can provide insight into how integration occurs and teachers move between disciplines (e.g., Akkerman & Bakker, 2011). Previous studies show that interdisciplinary education presents learning opportunities for teachers but also reveals challenges when collaborating with other teachers (e.g., Goos & Bennison, 2018; Pharo et al., 2012). A boundary-crossing perspective can provide a deeper understanding of teachers' opportunities and challenges, which has not been done before, if at all. This raises the following research question: "How do learning mechanisms of identification, coordination, reflection, and transformation occur within teachers when they collaborate in interdisciplinary university education?"

Method

Research design and participants

The present study used a qualitative design with a narrative approach and semi-structured interviews (Creswell & Poth, 2016; Spector-Mersel, 2010). Narrative research refers to a qualitative approach to collecting and analysing empirical material that focuses on various levels of stories: personal, collective, cultural and universal (Creswell & Poth, 2016; Denzin & Lincoln, 2005; Spector-Mersel, 2010). This study focused on teachers' narratives in interdisciplinary university education.

A group of 12 teachers working in different faculties at Utrecht University (UU) was selected to participate in this study (Creswell & Poth, 2016). The participants were selected using the convenience sampling method because they teach in interdisciplinary education, and the researcher was able to contact them to collect data (Creswell & Poth, 2016). Marshall et al. (2013) recommended using similar studies with the same design and research problem to choose the correct number of interviews. Studies by Hannon et al. (2018) and Visscher et al. (2019) examined interdisciplinary education in higher education and used semi-structured interviews with 12 and five participants, respectively.

This study focuses on teachers' learning mechanisms when collaborating with teachers in interdisciplinary education. Therefore, 12 teachers teaching or working in interdisciplinary courses were selected (see Table 1). Confidentiality was ensured by pseudonymising the data using unique codes for each teacher. The teachers participated in the study voluntarily and could withdraw or refuse their participation at any time. Data was gathered in the second semester of the academic year 2021–2022.

Table 1

Sociodemographic Characteristics of the Participants

Participant	Gender	Age	Educational experiences	Discipline	Involved in current interdisciplinary courses	Participant in *leergang interdisciplinair onderwijs*
1	Female	50	Teacher at UMC Utrecht Coordinator of three projects in interdisciplinary education	Medical biology	Covid and Society Selective Utrecht Medical Master (SUMMA)	No
2	Female	41	Teacher at the Faculty of Languages, Literature and Communication	Linguistics	Minor Medical Humanities	Yes
3	Female	41	Teacher at the Faculty of Languages, Literature and Communication Honours College	Historical Literature	Humanities Honours Programme	Yes
4	Male	55	Teacher at the Faculty of Law Director of Education Bachelor of Law Senior Fellow Centre for Academic Teaching and Learning	Law	Law and Linguistics	No
5	Female		Teacher at the Utrecht University College (UCU) UCU Honours Director	Philosophy	Identity Construction in East Asian Philosophy, Film and Literature Encountering China Student-Led Honours Seminar	No
6	Female	38	Teacher at the Faculty of Cultural Anthropology Interdisciplinary research	Anthropology	Security, Violence and Sovereignty From an Anthropological Lens,	Yes

					Graduate Honours Interdisciplinary Seminars (GHIS)	
7	Male	67	Teacher at the Department of Biology and University College	Biology	Evolution, Culture and Human Nature	No
8	Female	33	Program leader Honours College	Psychology	Interdisciplinary Honours Program	Yes
9	Male	32	Teacher at the Faculty of Law, Economics and Governance Member of Interdisciplinary Teaching and Learning	Applied Economics	Politics, Philosophy, Economics (PPE) Microeconomics	No
10	Male	55	Teacher at the Faculty of Chemistry UCU	Chemistry	Molecular and Biophysical Life Sciences (MBLS) Drug Innovation	Yes

Note. Participants 11 and 12 did not consent to the publication of their sociodemographic characteristics.

Instruments

Semi-structured interviews were conducted to gain a detailed and in-depth understanding of how learning mechanisms occur when teachers collaborate on teaching in interdisciplinary education (Baxter & Jack, 2008; Mahama & Khalifa, 2017). In addition, semi-structured interviews were chosen because teachers could explain their thoughts, experiences and expertise (Horton et al., 2004).

The analysis software NVivo was used to organise and analyse the data effectively. The trustworthiness of this study was ensured in several ways. First, a large group of 12 participants was selected to study the learning mechanisms. Second, a pilot of the interviews was conducted by interviewing a teacher working at UU who teaches interdisciplinary courses. Third, trustworthiness was ensured through a member check of the participants. Fourth, after the interviews, the teachers received a personal report illustrating their learning processes through the learning mechanisms. Finally, the teachers had the opportunity to provide feedback on their reports and whether they fit the labels used in this study (Zeegers & Barron, 2015).

Furthermore, investigator triangulation was applied by analysing the semi-structured interviews with two other researchers (Baxter & Jack, 2008). *Investigator triangulation* involves gathering and analysing data using several researchers (Wilson, 2014). Lastly, NVivo increased trustworthiness by carefully tracking and organising the data (Baxter & Jack, 2008; Patton, 1990; Yin, 2003).

Semi-structured interviews

Semi-structured interviews were conducted to gain a deeper understanding of teachers' learning mechanisms. An interview protocol with accompanying questions was prepared for the interviews. Some sample questions were: *"What went smoothly in the collaboration between disciplines/universities in course x?" "Why did that work?*" Or *"Were*

the disciplines of other teachers ever at odds with your own discipline/university when teaching course x?" "Can you tell me more about this?"

The questions emerged from the theoretical framework of the learning mechanism, where the research question was conceptualised and operationalised in some interview questions. However, Spector-Mersel (2010) suggested that in-depth interviews can influence participants because the researcher wants to extract information from them, while a narrative interview invites the participant to share their stories. Therefore, although some questions were structured and theoretically based, they were phrased in a way that allowed the teachers to share their thoughts, experiences and expertise (Horton et al., 2004). For example, the interview began with an open-ended question: "*Can you tell me what interdisciplinary education is to you?"*

According to Seidman (2006), there is no time frame for semi-structured interviews. Each interview lasted approximately 45 minutes and was conducted in Dutch or English. The interviews were fully transcribed, translated and audio-recorded with the teachers' consent.

Procedure

Twelve teachers from the UU were selected using a recruitment text and an information letter shared by the programme manager of the *leergang interdisciplinair onderwijs*. In addition, the researcher also recruited participants after the interviews by asking these participants if they knew any teachers who would like to contribute to this study.

Before the interviews began, the instrument was tested. The pilot test showed that teachers could also collaborate with teachers from different universities. All questions were adapted to ask not only about experiences with other disciplines but also with other universities. The word "university" was added to all questions.

Next, the researcher scheduled the interviews with the teachers. The interviews took place in the second semester of the 2021–2022 academic year. Before conducting the semi-

structured interviews, consent was obtained from the teachers. All twelve teachers gave their consent by signing the informed consent form. In addition, before the interviews, the teachers gave their verbal consent for the audio recording of the interviews. After the interviews, the teachers received a personal report. This report included the learning mechanisms that appeared during the interview for each participant and described how these learning mechanisms occurred within the interdisciplinary collaboration with their colleagues. This report provided participants with insight into their learning process via learning mechanisms. The teachers had the opportunity to provide feedback on their reports. Based on the feedback received, some sociodemographic characteristics have been adjusted, and one quote has been reformulated.

Analysis

The data was analysed using thematic analysis using hierarchical coding through a coding template (Brooks et al., 2015). The description of the themes was based on the teachers' personal stories (Creswell & Poth, 2016). First, the interviews were fully transcribed into the analysis software NVivo. Second, preliminary data coding was done, and a list of preliminary themes (a priori themes) was created based on the theoretical framework and operationalisation method (see Appendix A). The themes created were the four learning mechanisms: identification, coordination, reflection and transformation. In addition, the subtexts relevant to answering the research question were highlighted and coded in this step.

Third, the themes were organised into meaningful clusters to make the relationships between the different themes visible. In this step, the relationships were presented hierarchically. For example, identification consisted of meaningful clusters: assessing students, differences in teaching and hierarchy. Fourth, an initial coding template was created based on a subset of the data. The first four steps were performed based on four transcripts of the interviews.

Fifth, the original template was applied to three new transcripts. If necessary, the themes were adjusted, or new themes were added based on the theoretical framework. This process continued until no more data was left that would have been necessary to answer the research question. In this step, two researchers coded some of the data with the original template and discussed the differences in coding.

Last, the template was finalised and applied to the entire data set (see Table 2). The template was presented in a linear format with bold font and numbers to distinguish the different coding levels (Brooks et al., 2015).

Table 2

Coding Template

Learning mechanisms	Meaningful clusters	Description
1. Identification	Assessing students	Discussing the development and implementation of interdisciplinary assessments
	Differences in teaching	Feelings of frustration and stress about differences in how colleagues teach across disciplines/universities
	Hierarchy	Feelings of frustration and stress about not knowing colleagues with strategic positions in education or not having a strategic position themselves
2. Coordination	Speaking the same language	Learning to understand colleagues within their own discipline and on a didactic level
	Support	Whether receiving support (or not) from colleagues, team members, managers, funds and communities
	Clicking with colleagues	Having a personal relationship with colleagues
	Enthusiastic teachers	Teachers willing to develop and implement interdisciplinary education in addition to their daily work
	Network	Knowing colleagues who are also involved in interdisciplinary education
	Common themes	A shared common theme in teaching or developing interdisciplinary education
	Logistical arrangements	Scheduling, developing, implementing, promoting and financing
	Time	

		interdisciplinary education between faculties and universities
		Having the time to build personal relationships with colleagues and develop and implement interdisciplinary education
3. Reflection	Creating a set of perspectives	Being able to understand the boundaries of one's own discipline/university through the eyes of another discipline/university and thinking about how these boundaries can strengthen each other in interdisciplinary education or one's own discipline
	Gaining insight into one's own identity	Learning to understand one's own discipline and who the teacher is as a professional and person in one's own discipline through the eyes of another discipline/university
4. Transformation	Creating new educational practices	Developing new interdisciplinary courses and applying methods from other disciplines/universities in one's own discipline
	Changes in an interdisciplinary course	Changing the content of an interdisciplinary course

Results

Definition of interdisciplinary education

All participants were asked what interdisciplinary education meant to them, which led to the following definition: interdisciplinary education means conducting a dialogue with students and teachers from different disciplines, creating awareness of different perspectives and integrating knowledge to solve a complex problem. For example, Participant 4 described interdisciplinary education as follows:

> Yes, I think I can look at it three ways. I really enjoy looking at the law from different perspectives with a group of law students, but what I am discovering more and more now is to discuss the law with a mixed group of students at a somewhat meta-level, and especially if you then take stock of where you come from. So that is a form of interdisciplinarity, and then [there is] the third form, so what we are trying to do with language and law is get two groups together. So law and language students are together and learn to understand each other and can do things based on that.

Identification

Identification occurred within interdisciplinary teacher collaboration in assessing students, differences in teaching and hierarchy. Teachers revealed that in interdisciplinary collaboration with colleagues, discussions or feelings of stress and frustration arose when assessing students or experiencing differences in teaching between disciplines and universities. Participant 1, for example, stated that she was frustrated when collaborating with another university due to differences in working styles: "That straight-line thinking and precision and tightness, I just could not use my creativity at all, and I was completely blocked, and I could not work like that."

According to the data, when teachers began a dialogue with one another, it aided them in reaching a consensus in assessing students and understanding differences in teaching. According to Participant 11,

> I find that frustrating because it feels like you both are correct. So that is frustrating, but yes, the moment you express what you expect from each other and the other one agrees with that, or you will come to a consensus, it is just fine. So it is, yes, frustrating if you both have different expectations.

In addition, five teachers indicated that hierarchy occurred in the context of interdisciplinary teacher collaboration with colleagues from other disciplines at UU. The data showed that three of these five teachers experienced frustration and stress. The hierarchy also sometimes made it challenging to develop and teach interdisciplinary education. When asked by the researcher if this hierarchy hindered his teaching, Participant 10 responded as follows:

> Participant 10: Yes, sometimes it does.
>
> Researcher: In what way?
>
> Participant 10: Well, that you look elsewhere, that you do not do that within the walls of the UU but go across the road to Utrecht University of Applied Sciences.

Furthermore, according to Participant 3, this hierarchy made her feel like she had less influence on disciplinary and interdisciplinary education:

> Moreover, visibility is also important; our system is not built on interdisciplinary teaching. I do not feel supported because, on paper, [an interdisciplinary] minor is perfect; however, it will only hold you back in the end. So that has a lot to do with acknowledging and appreciating, and that is the story. I have a feeling that this story is not heard. (Participant 3)

However, these five teachers did feel supported by their colleagues.

Coordination

Coordination took place in the context of interdisciplinary teacher collaboration in social interaction, common themes and the organisation of interdisciplinary education. Social interaction includes speaking the same language, providing support, clicking with colleagues, and having enthusiastic teachers and a support network. Common themes stand on their own. For example, organising interdisciplinary education includes logistical arrangements and time. The data suggests a difference in how coordination occurred within interdisciplinary teacher collaboration between colleagues from different disciplines and between universities. Nine teachers expressed that speaking the same language when engaging in interdisciplinary collaboration was crucial. These teachers collaborated with colleagues from other disciplines. According to Participant 2,

> Then I thought, "Yes, of course, you have to say that out loud to each other". Yes, and that is speaking the same language. However, I think, yes, we have in common that we are both teachers, so in everything about didactic methods, or assessments or rubrics, we speak that language. So it was only the content part you needed from each other.

Participant 7 also emphasised the importance of speaking a shared language: "Another crucial point is, of course, communication. You often talk about things within a discipline in jargon, and you understand that. You also must learn to speak in an accessible language to explain it adequately to other disciplines". Teachers who collaborated with teachers from other universities did not indicate that speaking the same language is crucial for them when engaging in interdisciplinary collaboration.

In addition, eight teachers mentioned that feeling supported by colleagues, managers, directors, funds and co-teaching was necessary for interdisciplinary teacher collaboration. Five of these eight teachers stated they experienced support through participation in the *leergang interdisciplinair onderwijs*. Participating in this course was valuable for the teachers

because they felt supported by colleagues who also collaborated in interdisciplinary education and were able to share their experiences and network. As Participant 8 pointed out,

> That would be nice to spar with colleagues about interdisciplinarity occasionally, and I could do that in the *leergang interdisciplinair onderwijs*. I really liked that about the *leergang interdisciplinair onderwijs* because then you will, of course, meet people who are also involved in interdisciplinary education but at the faculties.

However, the data indicated that organising interdisciplinary education through interdisciplinary teacher collaboration between teachers from departments of different faculties within UU and other universities could be complicated. All programmes within UU and between different universities had rules with which they needed to comply, as the following participants shared:

> Participant 4: Yes, unfortunately, it is hard to [collaborate], and those are the practical problems you run into, especially at UU, where it is organised in silos, which makes coordination very difficult.
>
> Researcher: And that is the coordination with other departments from other faculties?
>
> Participant 4: Yes, in particular, other departments in other faculties.

Participant 2 confirmed these logistical difficulties:

> And those practical matters are the biggest challenges of interdisciplinary education. So for the minor [Medical Humanities] it is very complicated because it works differently with the other faculty. They have different time slots, periods, and even registration systems. Yes, and with that master, yes, we are now also running into everything, like scheduling and payments.

In addition, according to Participant 9, teachers' interdisciplinary collaboration was hindered by a lack of time. This was especially the case for teachers who collaborated with teachers from other disciplines:

> Yes, that is a good question, so you often get a little more (full-time equivalent) FTE for these courses than I would get when teaching a mono-disciplinary course within economics. Yes, whether that is really sufficient compensation, from a purely calculating point of view, say a flat calculation. Especially if you include everything that includes those core teacher meetings, those crash courses, those extracurricular things, if you count all that together, then you do not get enough time, or that is not proportional.

Nevertheless, despite this lack of time, teachers like Participant 9 believed that interdisciplinary education was important enough to prioritise "because I really like it, and I find it valuable, and I also have a long-term perspective".

Reflection

Reflection took place in the context of teachers' interdisciplinary collaboration in learning by creating new perspectives and gaining insights into their own discipline. In this study, the teachers showed that they learned to look at their own discipline or themselves through the eyes of other disciplines and universities. As Participants 7 and 6 showed, this led to teachers having a better understanding of the boundaries of their own discipline and of the university as a whole through interdisciplinary collaboration:

> Yes, I think that is somewhat unavoidable, but it is indeed very interesting that at a certain point, you realise — what I used to realise less — is that you understand the limits of your own discipline more quickly, or that you understand the strengths but also the limitations of the methods of your own discipline. At first, I did not really see the value, as a biologist, of source research of history. So then you also look at a certain point, there is a historian who uses that evolutionary concept to explain better what has happened at some time and at some point, you realise the importance of that kind of source research. (Participant 7)

> And that I really see more value of — okay, some things I can only understand if I have that legal perspective. So I really see that the approach my colleague is using helps me understand my discipline better and vice versa. (Participant 6)

Eight teachers also indicated that interdisciplinary teacher collaboration helped them gain insights into who they were as professionals or as people within their own discipline. According to Participants 8 and 5,

> But in a collaboration that does not go well, you still notice that you have a certain pair of glasses. So you will reflect a lot on, okay, what are those glasses? What are the boundaries of my discipline? My co-worker is more black-and-white than I am and all about efficiency and frameworks. And I am much less rigid than, "Oh, yes, those students, oh, they do that and we can try out this (…)", And she makes the lists and the diagrams and the tables, and that is very efficient in my opinion, but I do not work that way. (Participant 8).

> So really, it brought me further in my own discipline and my own, you know, becoming a human being or something. However, in a way, you know, maybe that is what I say — that I am like this as a philosopher, human being and educator. (Participant 5)

The results show that all teachers were able to reflect on their interdisciplinary collaboration.

Transformation

Within interdisciplinary teacher collaboration, a transformation occurred in the creation of new educational practices and changes in interdisciplinary courses. Six teachers shared that, as a result of interdisciplinary collaboration with colleagues from different disciplines and universities, they implemented the working methods of other disciplines and universities in their own discipline or organised new interdisciplinary courses. The data

indicates that five of these teachers experienced difficulties in organising interdisciplinary education, but this did not prevent them from organising new interdisciplinary courses. According to Participant 10,

> My challenge is to organise a pharmacy course in such a way that I am not only working with colleagues within pharmacy, chemistry and biology, but I also want to look at how I can give students and teachers from other faculties a role in this course.

Nine teachers mentioned that they were working to further develop the current interdisciplinary course they were teaching. In addition, these teachers collaborated with teachers from other disciplines and universities. Participant 3 stated: "Moreover, this year, the minor has actually become a bachelor's course. We offered it to bachelor students in law, and next year we will split this bachelor course into two courses and the year after that into four courses".

Nevertheless, the data suggests that transformation did not occur for three teachers. Possible explanations for this result are that these teachers had either retired or felt they were already working from an interdisciplinary perspective.

Discussion

The current study aims to provide an in-depth understanding of how learning mechanisms of identification, coordination, reflection and transformation occur within teachers when they collaborate in interdisciplinary university education. Identification takes place in assessing students, differences in teaching and hierarchy. Coordination happens in social interaction, common themes and organising interdisciplinary education. Reflection occurs when new perspectives are formed, and insight into one's own identity is gained. Finally, transformation takes place by creating new educational practices and changes in interdisciplinary courses.

Identification

The current study shows that assessing students and differences in teaching can lead to discussions and feelings of stress and frustration, where dialogues can help teachers reach a consensus. According to studies by Akkerman and Bakker (2011), Akkerman and Bruining (2016) and Ryymin and Lamberg (2021), this result is in line with the concept of identification, which refers to having a dialogue to gain insight into another practice. This concept also describes how teachers can follow another practice and be accepted by others in different domains. For example, in interdisciplinary collaboration, teachers may unconsciously expect others to assess students and teach the same way they do in their own discipline or university. Regarding the present study, this may explain why teachers start a dialogue with each other. Furthermore, identification focuses on meaning-oriented learning processes expressed through student assessment and differences in teaching (Akkerman & Bakker, 2011).

In contrast, the hierarchy experienced by several teachers prevented them from offering and developing interdisciplinary education. This finding is likely related to Mahon et al.'s (2017) theory of practice architectures of university education. This theory states that practices are shaped by architectures consisting of cultural practices and material-economic and socio-political arrangements found in particular practices. Practice architectures focus on how specific practices can persist or dominate over other practices. One possible explanation for why teachers experience hierarchy may lie in the socio-political arrangements constraining and enabling academic regulations and procedures, university hierarchies and research collaborations.

This research shows that teachers need discussions or feelings of frustration, to get to know and understand another discipline or university or to learn how they work in another discipline or university. However, feelings of hierarchy can hinder interdisciplinary collaboration among teachers.

Coordination

The results indicate that interdisciplinary teacher collaboration works more smoothly through social interaction and common themes. Several teachers experienced support such as co-teaching and working with common themes. This result may be explained by the fact that teachers who co-teach in interdisciplinary university education encourage the exchange of ideas in different fields (Pharo et al., 2012). Another possible interpretation of this result is that interdisciplinary teacher collaboration between teachers is smoother after joint stages of planning, implementation and evaluation (Chaovanapricha & Chaturongakul, 2020).

Furthermore, this study suggests that having a community like the *leergang interdisciplinair onderwijs* is valuable for teachers because they can share their interdisciplinary experiences. This also supports a study by Lu (2020), which shows that sharing challenges (e.g. teaching practices and curricula of other disciplines) improves the teaching of disciplinary content.

Nevertheless, this study indicates that organising interdisciplinary education hinders teachers' interdisciplinary collaboration. One explanation for this could be that interdisciplinary teacher collaboration may be impeded by existing institutional arrangements and cultural barriers that maintain disciplinary silos, as shown in studies by Goos & Bennison (2018) and Hannon et al. (2018). In addition, a study by Boden et al. (2011) suggested that interdisciplinary university education leads to organisational challenges because universities are structured according to disciplinary thinking, creating decision-making channels that make it difficult to align and support interdisciplinary activities (Kans & Gustafsson, 2018). Another finding was that teachers experienced a lack of time in interdisciplinary teacher collaboration, which aligns with studies by Brand and Triplett (2012), Pharo et al. (2012) and Tiongson (2018), showing that interdisciplinary education is more time-consuming than disciplinary education.

What is surprising is that within interdisciplinary teacher collaboration between different disciplines and universities, differences can be found in the social interaction and the organisation of interdisciplinary teaching. However, the reason for this finding is not apparent. Teachers collaborating with other universities within a familiar discipline may have different experiences with social interaction and organising interdisciplinary teaching.

This section has reviewed, that coordination emphasises practice-based learning processes through social interaction, common themes and the organisation of interdisciplinary education (Akkerman & Bakker, 2011). To enable interdisciplinary collaboration between teachers, teachers must experience personal support and receive organisational support.

Reflection

This study suggests that reflection in interdisciplinary teacher collaboration focuses on meaning-oriented learning processes by creating a new perspective and gaining insight into one's own identity (Akkerman & Bakker, 2011). This finding is consistent with Lave and Wenger's (1991) theory of situated learning, which sees learning as part of a community of practice and emphasises collaborative effort in meaning-making. Teachers who work together and share a common goal and passion are seen as communities of practice (Sherer et al., 2003; Viskovic, 2006). One possible explanation for the teachers' reflective capacity in this study is that their identity, meaning, community and practices are interrelated (Goh, 2019). This means that an individual is seen as a social participant — a meaningful individual whose identity develops through participation in the social world (Goh, 2019). The current study suggests that teachers better understand the other discipline or university, their own discipline or university and themselves because they can cross boundaries through interdisciplinary teacher collaboration and thus make meaning of their discipline and who they are as individuals.

Another possible interpretation of this finding is that in order to be able to learn, teachers must be willing to learn and improve their own practice (Kyndt et al., 2016). When these elements are present, this leads to participation in various learning activities (e.g. Burn et al., 2010; Hodkinson & Hodkinson, 2004; Lohman, 2006, 2007). In this study, the teachers are involved in interdisciplinary education in different ways and exhibit a willingness to learn and enhance their own practice.

Transformation

This study indicates that through interdisciplinary teacher collaboration, teachers implement the working methods of another discipline or university in their own discipline or develop new interdisciplinary courses. This contrasts with previous findings that show that teachers' interdisciplinary collaboration is hindered by hierarchy and the organisation of interdisciplinary education. For example, studies by Cortese (2003), Moore (2005) and Savelyeva (2012) demonstrate that traditional departments and the compartmentalised structure of universities with their disciplinary boundaries impede integration in curricula, teaching and collaboration within communities. Therefore, given previous studies and the findings of this study, it is surprising that the teachers in this current study are still implementing methods from another discipline or university in their own discipline or developing new interdisciplinary courses.

However, transformation may occur among the teachers in this study because, as indicated by reflection, they have the will to learn and improve their own practice (Kyndt et al., 2016). Furthermore, interdisciplinary education focuses on team activities that support knowledge integration and strengthen collaborative skills while crossing boundaries (Kyndt et al., 2016). Similarly, studies by Engeström (2015) and Paavlova et al. (2004) noted that transformation occurs in practice by combining different perspectives and patterns of activities. In this study, as suggested earlier, it could be that teachers have the desire to learn

and improve their practice, which encourages them to integrate knowledge from different disciplines or universities and make meaning of these differences. This may lead them to implement working methods from another discipline or university into their own discipline or to create new interdisciplinary courses. This section has reviewed that transformation emphasises practice-based learning processes by creating new educational practices and changes in interdisciplinary courses (Akkerman & Bakker, 2011).

Limitations

A limitation of this study is that the researcher had to rely on teachers' recollections of their experiences with interdisciplinary education. For example, some interviews were not conducted during an interdisciplinary course or immediately after completing an interdisciplinary course. Because it was difficult to recruit teachers to participate, it was decided to interview teachers who had taught or developed interdisciplinary education or were already working in interdisciplinary ways that did not involve teaching.

Another limitation of this study is that it did not specifically investigate which disciplines or universities came together to collaborate or what topic they were addressing. Further research could be useful to explore which disciplines or universities collaborate, on what topics and the impact this might have on collaboration.

Implications

Despite its limitations, this research contributes to understanding how teachers learn at the boundaries of a discipline. For example, one issue raised by this study is the hierarchy experienced by several teachers. Previous studies on interdisciplinary teacher collaboration barely touched on teachers' experiences with hierarchy. As a result, further research could be beneficial in better understanding the hierarchy in interdisciplinary education and what teachers require if they encounter it. According to a study by Mahon et al. (2017), this hierarchy can be explained by *social-political arrangements*, which are arrangements or

sources (e.g. organisational rules, social solidarities, hierarchies, communities and organisational relationships) that shape how people can relate to other people or objects in practice and facilitate or constrain that relating.

In addition, a longitudinal study could be conducted in the context of interdisciplinary teacher collaboration to better understand how their learning process changes over time and how they develop as professionals: teacher-professional learning. (De Jong et al., 2021). *Teacher- professional learning* (TPL) refers to an ongoing work-related process that leads to a change in cognition or behaviour and, thus, learning (Bakkenes et al., 2010; Zwart et al., 2008). Opportunities for professional development also arise for teachers when they collaborate across disciplines. Furthermore, teachers' learning potential has been shown to increase when they participate in learning activities with colleagues from the same school, department or year level (Desimone, 2009; Levine & Marcus, 2010). Insight into teachers' professional development can therefore help improve interdisciplinary education.

For future research, it is recommended to investigate how teachers' and students' learning mechanisms operate in an interdisciplinary course. If teachers gain insight into how students learn in interdisciplinary education, they can better understand students' learning processes. Students taking an interdisciplinary course can improve their critical thinking, problem-solving, creativity and innovation skills and develop collaboration and communication skills (Cotantino et al., 2010; Cowden & Santiago, 2016; Mobley et al., 2014; Styron, 2013). Students' preparedness, prior education and professional experiences also shape their interdisciplinary learning, which can present the same challenges for teachers when developing teaching methods and approaching epistemological divides in interdisciplinary education (Bradbeer, 1999). If teachers better understand how students learn in interdisciplinary collaboration, this can help them improve interdisciplinary education (Ashby & Exter, 2018; Klein, 2005).

Furthermore, the findings of this study have several practical implications. First, in light of the results, directors, managers and colleagues need to dialogue with teachers who contribute to interdisciplinary education. Maintaining a dialogue with teachers and asking them how they experience interdisciplinary education will help provide adequate support for teachers to continue to teach, develop or implement interdisciplinary education.

In an interview, one teacher pointed out that interdisciplinary collaboration among teachers could run more smoothly if faculties or UU better informed teachers about how to teach, implement or develop interdisciplinary education across disciplines. It also may help teachers if they know what steps to take to contribute to interdisciplinary education, what kind of support they can receive from the faculties or UU, where to find that support and how they can arrange or combine interdisciplinary education with disciplinary education.

Finally, several teachers mentioned that co-teaching and the *leergang interdisciplinair onderwijs* were valuable to them. Therefore, a recommendation would be to investigate the possibility of co-teaching in interdisciplinary courses and the continuation of the *leergang interdisciplinair onderwijs*.

Conclusion

The current study provides insight into how teachers' learning mechanisms of identification, coordination, reflection and transformation occur when they collaborate in interdisciplinary university education. The results of this study support previous findings on the challenges and opportunities teachers face when engaging in interdisciplinary collaboration (Akkerman & Bakker, 2011; Chaovanapricha & Chaturongakul, 2020; Hannon et al., 2018; Pharo et al., 2012). Through interdisciplinary collaboration, teachers create new perspectives on their own discipline or university and can integrate knowledge from different disciplines or universities. However, interdisciplinary collaboration can be hindered by the organisation of interdisciplinary education and hierarchy. Therefore, further research is

recommended to better understand the hierarchy associated with interdisciplinary collaboration. Finally, it is important to maintain a dialogue with teachers in interdisciplinary collaboration so that they can share their experiences and indicate what they need to continue in interdisciplinary education.

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Appendix A
Operationalisation of the Learning Mechanisms

Research question	Conceptualisation	Operationalisation/themes	Examples of interview questions
How do learning mechanisms of identification, coordination, reflection, and transformation occur within teachers when they collaborate in interdisciplinary university education?	Identification	Othering Legitimating coexistence process	Were the disciplines of other teachers ever at odds with your own discipline when teaching course x? Can you tell me more about this? If there was tension, what does that do to you?
	Coordination	Communicative connections Translations Boundary permeability Routinisation	What went smoothly in the collaboration between disciplines in course x? Why did that work? What ensured that all disciplines involved could work together efficiently in course x? Why do you think this worked?
	Reflection	Creating a set of perspectives Creating a new identity	Do you look differently at your own discipline through the eyes of discipline x? Is this about one or more perspectives?
	Transformation	Changes in practices New practices	If you would teach this course again next year, would you do it differently next year based on these experiences with the other discipline/university? What new things do you apply in education, or

	would you like to apply based on your experiences with interdisciplinary education?