Learning, Culture and Social Interaction 40 (2023) 100716

Contents lists available at ScienceDirect

Learning, Culture and Social Interaction

journal homepage: www.elsevier.com/locate/lcsi

Full Length Article

Construction and enactment of interdisciplinarity: A grounded theory case study in Liberal Arts and Sciences education

Xin Ming [a,*,1], Miles MacLeod [a,2], Jan van der Veen [b,3]

[a] University of Twente, the Netherlands
[b] Eindhoven University of Technology, the Netherlands

ARTICLE INFO

Keywords:
Interdisciplinarity
Interdisciplinary education
Liberal Arts and Sciences
Group work
Challenge-based learning
Grounded theory

ABSTRACT

This article explores how interdisciplinarity is constructed and enacted in a Liberal Arts and Sciences (LAS) educational environment, when self-tailored personal academic development is intertwined with collaborative group work involving various disciplinary input. A case study taking a grounded theory approach analyzed how interdisciplinarity emerged from collaborative groupwork dynamics in which students' academic identities manifest and interact. Academic identity in LAS contexts is complex: Individuals' disciplinary identities intersect with a generic program-bound identity shared by all students. Disciplinary identity was not only unique for each student, but also showed diverse configurations among the LAS population, as revealed in three disciplinary profiles: disciplinary specialists, topic experts, and identity explorers. Interdisciplinarity, accordingly, has different meanings and entails different journeys of academic growth. The interplay between and among the intersectional academic identities constitutes different groupwork dynamics and leads to different learning experiences. Comparing three patterns of groupwork experience—non-disciplinary, monodisciplinary and interdisciplinary—the article argues for two key concepts crucial for experiencing interdisciplinarity: disciplinary enablement and disciplinary transaction. To make sense of interdisciplinarity in LAS contexts, the article further looks into tensions perceived by students regarding specific groupwork as well as long-term academic development. The tensions reflect two dimensions of knowledge and knowledge work that both LAS students and LAS education in general need to reconcile, namely, specification and specialization versus generalization and integration.

1. Introduction

As higher education increasingly promotes interdisciplinary approaches, the dialectical relationship between interdisciplinarity and disciplines in learning has attracted academic attention. Current work has addressed the nature of interdisciplinarity, learning outcomes of interdisciplinary programs and courses, interdisciplinary competencies, and the design of interdisciplinary education. In addition, scholars are starting to examine the ways interdisciplinary learning is constructed and enacted in specific and actual

* Corresponding author at: Department of Philosophy, University of Twente, Drienerlolaan 5, 7522 NB Enschede, the Netherlands.
E-mail addresses: x.ming@utwente.nl (X. Ming), m.a.j.macleod@utwente.nl (M. MacLeod), j.t.v.d.veen@tue.nl (J. van der Veen).
[1] University of Twente, Department of Philosophy and Department of Teacher Development (ELAN), Enschede, the Netherlands.
[2] University of Twente, Department of Philosophy, Enschede, the Netherlands.
[3] Eindhoven University of Technology, Eindhoven School of Education, Eindhoven, the Netherlands.

https://doi.org/10.1016/j.lcsi.2023.100716
Received 17 March 2022; Received in revised form 5 April 2023; Accepted 13 April 2023
Available online 3 May 2023

educational settings. One approach employed takes a sociocultural perspective and studies academic identity formation (Spelt et al., 2017). However, while most research applying this perspective looks at settings involving students from different disciplines, one type of interdisciplinary environment has remained relatively unexplored: Liberal Arts and Sciences (LAS) education.

LAS students are not confined to certain specialized disciplinary regimes. Instead, they choose from a broad range of different types of knowledge and tailor unique learning trajectories following their own interests and ambitions (Tubbs, 2014). Such students are thus, in a sense, intrinsically interdisciplinary. The open structure of LAS education often favors project-based learning and group work, which allows students with distinct expertise to collaborate towards common goals. Therefore, LAS programs, as a counterforce to an excessively specialized disciplinary academic culture, present a different set of conditions under which interdisciplinary education takes place.

This article explores how interdisciplinary learning is constructed and enacted through individual development and interpersonal interactions that intertwine in LAS education. Towards this goal, we studied a project-based course in a Dutch LAS program. To make sense of interdisciplinarity in this particular educational environment, we closely examined students' academic identity formation and learning experiences. We investigated, for instance, how students orient themselves throughout their personal academic development, how the environment enables interdisciplinary interactions, and how students and environment mutually shape each other. Because such educational contexts not only trigger complex dynamics, but are also rather untraditional and underrepresented in research on interdisciplinary education, we took a grounded theory approach to elicit and capture rich representations of and connections between individual experiences and educational contexts in one specific case of LAS education.

We report our study following a standard structure to facilitate reading and understanding, despite the underlying grounded process and inductive logic. The next section introduces research on interdisciplinary education, in general and in the specific context of LAS education. In Section 3 we present our case, detailing the specific educational setting where the research took place. In Section 4, we introduce our methodology, especially our rationale for grounded theory research, methods, and procedures. Section 5 discusses our findings about the construction and enactment of interdisciplinary education in this LAS context. In the concluding sections, we reflect on theoretical and practical implications of our study.

2. Theoretical context: interdisciplinarity and LAS education

While the modern structure of education is largely disciplinary, based on academic divisions of disciplines featuring distinct worldviews and power systems (Klein, 2006), the integrative nature of knowledge and real-world demands have boosted the presence of interdisciplinarity in academic research and education (Van den Beemt et al., 2020). For the exploratory purposes of our study, we take a broad approach to what kinds of practices, experiences or attitudes could count as "interdisciplinary": "a variety of different ways of bridging and confronting the prevailing disciplinary approaches" (Huutoniemi et al., 2010, p. 80), thus an overarching generalization that subsumes ideas such as cross-, multi- and transdisciplinarity. In this regard, the range of interdisciplinary endeavors can vary from juxtaposing knowledge and methods from separate disciplines, to restructuring and integrating existing disciplinary approaches, and, more radically, questioning disciplinary grounding as prerequisite in knowledge work (Klein, 2010). Interdisciplinary learning, on this basis, occurs outside or between traditional single disciplinary spaces, involving an ability to operate outside such spaces and social interactions or cognitive integration beyond or with other disciplinary backgrounds.

Earlier research on interdisciplinary research has developed a typology of different kinds or degrees of interdisciplinarity—for instance distinguishing between multi-, inter-, and transdisciplinarity (Choi & Pak, 2006; Klein, 2010). These distinctions, however, are by no means univocal and undisputed (Huutoniemi et al., 2010). Many other studies have focused on the design of interdisciplinary education, often in relation to its effectiveness in terms of learning outcomes (Costa et al., 2019; Lattuca et al., 2017). Comparably, scholars have sometimes taken advisory or normative positions to prescribe practical design criteria, recommendations and "do's and don'ts" for creating and implementing interdisciplinary education (Newell, 1990; Vink et al., 2017). Curricular, pedagogical, and organizational factors behind interdisciplinary educational practices have also been surveyed and described, pinpointing categories, facilitators, and challenges of interdisciplinary designs (Power & Handley, 2019; Van den Beemt et al., 2020). The development of interdisciplinary competency frameworks is another line of earlier research that has gained attention (Claus & Wiese, 2019; Lattuca et al., 2013). Research focusing on the micro-level, investigating how interdisciplinarity happens and emerges, how it is constructed and enacted in educational settings, is still under-developed. Recently, two relevant studies inquired into the nature of interdisciplinary learning. Sauzet (2022) investigated the formation of professional responsibility in interprofessional educational settings; Lindvig (2022) analyzed the co-existence of programmatic and intentional versus tacit and operational manifestations of interdisciplinarity ("loud versus soft voices") in academic programs.

While interdisciplinary education has been largely approached as a cognitive learning process of intellectual development, scholars have also addressed learning from a sociocultural perspective. Rooted in the philosophy of social constructivism, the sociocultural lens sees knowledge as co-constructed by individuals and social processes (Palincsar, 1998): Knowledge work thus coincides with interpersonal socialization; identity formation and problem-solving go hand in hand (Osbeck & Nersessian, 2010). Interdisciplinary practices are, accordingly, cognitive-cultural systems (Nersessian, 2019), in which cognitive practices of integration are in congruence with social interactions and transactions throughout problem-solving processes (Nersessian & Newstetter, 2014). Education, following this emphasis on social interactions, is viewed as constructed by the involved individuals and nested in inextricably interconnecting human activities and social contexts.

The sociocultural lens construes learning outcomes as personal identity development that occurs through socialization. While disciplinary cultures play a critical part in students' development of academic identities (Baker & Lattuca, 2010), interdisciplinary environments, where students of different academic backgrounds come across, further mediate students' perception, self-development

and learning experience. Students' interdisciplinary identities, accordingly, emerge and develop through negotiation between actors (McNair et al., 2011) and between different disciplinary identities (Lingard et al., 2007). Environments involving multiple disciplines, while extending students' perspectives, might also strengthen and reinforce their disciplinary identities rather than breaking down rigid disciplinary obligations and loyalties (Geschwind & Melin, 2016). A similar examination of tensions between disciplinary identities and interdisciplinary engagement (Holley, 2015) revealed the role of disciplinary backgrounds in developing interdisciplinary identities: Elaborate disciplinary knowledge may seem contradictory to interdisciplinary curricula, but a lack of disciplinary foundations does obstruct engagement.

Identities can take many shapes and can be based on many features. Vignoles et al. (2011) distinguishes between personal, relational, and collective identity, arguing that identity can be shaped in individual sense-making processes, in the interaction with others, and by membership of groups. The first two may not always be easy to distinguish within the time frame of one educational unit, but a distinction between students' individual academic identity development and the institutional identity affiliated with the program they form part of (Gee, 2000) appears to be important for our study. In traditional disciplinary programs, students' academic identity is more strongly guided by the program. What happens if academic identity development becomes more of an individual process? And how is the program identity aligned with such individual developments? In our study we focus on academic identity, while other aspects of private identity are left in the background unless put forward explicitly by participants, relating to for instance the recognition of the program-based collective identity.

Educational contexts where interdisciplinary learning is implemented typically take disciplines as given, both knowledge-wise and institution-wise. The shaping of interdisciplinary identities has hence often been investigated among already professionally-oriented and specialized (often doctoral) students (Baker & Lattuca, 2010; Geschwind & Melin, 2016; Holley, 2015). In such contexts, interdisciplinary learning offers an additional perspective on top of the disciplinary foundations. Land (2012) frames it as a threshold concept offering troublesome knowledge which eventually facilitates entirely new ways of thinking. However, curricula in which students immediately dive into all-encompassing environments before establishing firm disciplinary identities are becoming more prominent.

Recently, Liberal Arts and Sciences (LAS) education has gained popularity in Europe as a novel form of undergraduate education to provide students with flexibility for the current knowledge economy in a globalized world (Van der Wende, 2011). LAS education offers students the broadness and freedom that also characterizes traditional liberal arts programs. Most LAS programs explicitly try to connect natural and technical sciences with social sciences and humanities and do so in the context of grand societal challenges, thereby explicitly fostering interdisciplinary development. The open structure of LAS education often invites project-based learning and group work. Well-described examples of such LAS programs include the University of Amsterdam (Bog & Van der Wende, 2016) and Maastricht University (Kovačević, 2022). Such interdisciplinary environments raise new questions about academic identities and trigger further discussions about social dynamics in education.

Unlike typical educational programs, which inherently embody specialized identities with explicit disciplinary orientations and pre-defined disciplinary boundaries, LAS foregrounds students' individual development by emphasizing self-orientation within flexible curricula across and beyond traditionally separated disciplines (Becker, 2015). Students are thus allowed to actively orient themselves, choosing and constructing their particular academic identities. Scholars have advocated the LAS-based college structure (Becker, 2015) and examined its effectiveness for various learning objectives (Sklad et al., 2016), but have not yet scrutinized how interdisciplinary learning takes shape within such contexts or how students' identities develop in response.

To investigate this, we studied a project-based course in a Dutch undergraduate LAS program, which adopted a college structure, featuring close learning environments and social communities. Through the sociocultural lens, we witnessed how interdisciplinary learning is constructed and enacted in this broad social-educational LAS environment, where disciplinary identities are concurrently sought for, negotiated, and balanced in group work and students' academic development. Next, we sketch the educational, organizational and sociocultural features of this case, clarifying its particularity and generalizability as an interdisciplinary context.

3. Practical context: the SALT program

Despite skepticism that “it is difficult to have interdisciplinary programs on the undergraduate level because students do not bring to them the kind of disciplinary training that one gets in a standardized program” (Turner, 2000, p. 53–54), many Dutch universities have established undergraduate LAS university colleges to prepare students for grand societal challenges. One such university is located near the eastern border, small-scale as an institution but with a prominent campus, which is rare in this high-tech lowland country. Identified as a technical university, it has a large faculty in humanities and social sciences, specializing in human and social issues related to technological development. This university hosts a three-year undergraduate program – Technology and Liberal Arts and Sciences (SALT[4]). Launched in 2012, SALT embraces community-based LAS education and focuses on cultivating “new engineers”, envisioned as global citizens capable of solving worldwide problems.

The interdisciplinary nature of this LAS curriculum is boosted by two hallmarks in its educational strategy which themselves strongly fit SALT's vision for future engineers. The first is self-designed and self-regulated learning. SALT offers electives from a broad range and allows students to tailor their own educational paths rather than follow a fixed curriculum. Phrases expressing this individualized orientation such as “Design your own program” and “You are in charge” frequently appear on its official website. Despite

[4] SALT is a pseudonym.

this freedom, students share some common activities. Students need to pass compulsory courses in the early semesters covering the domains of mathematics, natural sciences and social sciences. The program also demands students' constant reflection on personal development to modulate and steer their self-directed learning. Project-based learning is the second SALT hallmark. Students, through hands-on projects, are expected to learn effectively, by pursuing their own interests, putting knowledge into practice, obtaining viable skills and developing collaborative capacities through social learning (Bell, 2010). The program's first four semesters, before students enter the highly individualized final year of studying abroad and graduating, are each organized around semester projects (SPs) with distinct themes.

Interdisciplinarity is thus institutionalized within the SALT academic culture on two levels. On the individual level, the combination of self-oriented flexibility to choose diverse disciplinary electives and compulsory education in different domains encourage students to acquire expertise beyond fixed disciplines. Collectively, the project-based learning entails collaboration among students with different academic interests and expertise, leading to interdisciplinary groups and group work. As the collaborative context affects and reflects the collaborating individuals, interdisciplinary personal development and group work intertwine in SALT education.

The fourth and final SP (SP4)—the case of our study—deals with an especially comprehensive and challenging theme: wicked problems (see Fig. 1 for the structure of SP4 in 2020). Over 19 weeks, students were given substantial freedom to determine topics, form groups, and work towards identifying and addressing grand real-world challenges by devising interventions through, according to the syllabus, "multidisciplinary solutions and systems thinking". In the teaching materials of SP4, the terms multi- and interdisciplinary are used interchangeably.

The process is organized into four episodes. SP4 starts with a prologue: a one-week introductory phase that ends with a so-called pressure-cooker preparation session. In that session, students decide on topics they will tackle and form groups of about 14 persons each. After this, the actual group-based project work follows in three phases.

The first phase ("Mapping and Modelling") gives each group 5 weeks to study their chosen problems. Students analyze the problem from different angles, decompose it into heterogenous constituents, and map and model it so exhaustively possible by describing constituent components and their interrelations. The most pressing components are selected as "critical issues". In the 9-week second phase ("Mitigation"), the large groups divide into smaller "expert teams". With 2 to 4 persons each, expert teams address the overarching problem by developing and applying specific types of expertise to create mitigation strategies for the identified critical issues. While devising and elaborating mitigation strategies, groups contact and consult with "domain expert[s]" external to the project, whose roles are multiple: They inspire and guide students to develop mitigation strategies, comment on drafts for improvement, and assess students' work by giving feedback on their end-of-semester reflections. In the third phase ("Integration"), students return to their large groups. Over these remaining 4 weeks, students are expected to communicate about, reflect on, and compare individual strategies, and then interrelate and synthesize them into a collective final report addressing the overall problem. Throughout the process, each group is led by a "group leader", selected in advance upon application, responsible for the cohesion of the heterogeneous group in terms of collaboration and deliverables. The project is led by two staff members—a semester coordinator and a project coordinator—who are both highly involved in SALT and know the students already from previous semesters. As shown in Fig. 1 and explained below, the schedule for the final two phases differed slightly for the 2020 cohort.

In 2020, SP4 welcomed 48 SALT students. During the pressure-cooker preparation session, they decided on three

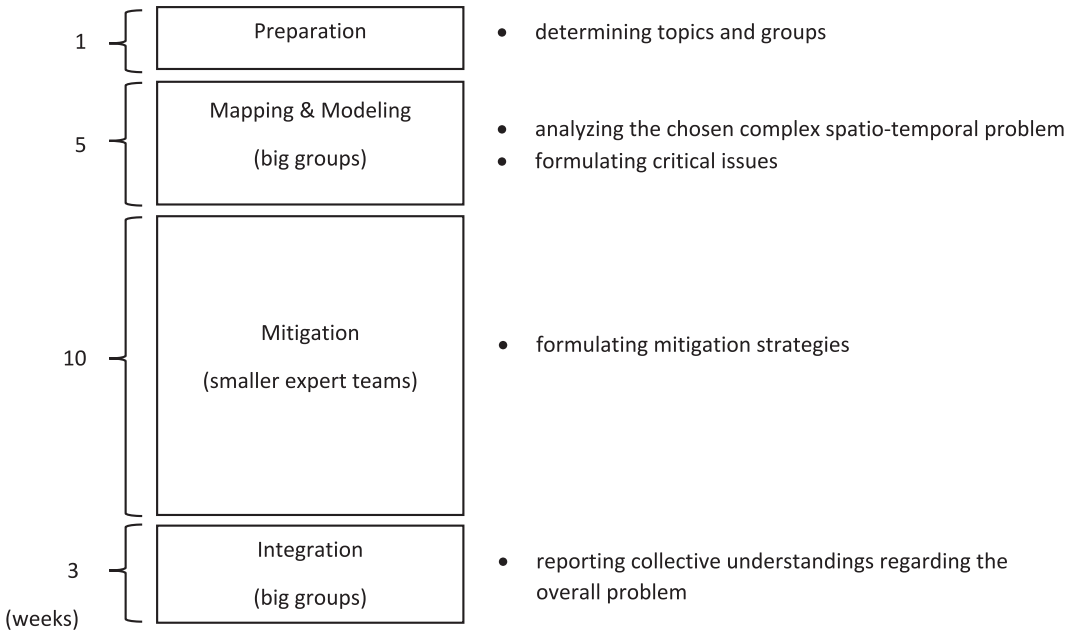

Fig. 1. Structure of SP4 in 2020 (differs from the usual schedule due to Covid-19).

topics—sustainable energy, human trafficking, and pandemics—and accordingly formed three groups. However, once groups and expert teams had been formed and moved onto the Mitigation phase, COVID-19 hit the country. After a one-week halt, all educational activities had to be transferred online. The resulting chaos required much from coordinators to maintain communication and facilitation for the students working on SP4. It required even more from students, especially in terms of responsibility and autonomy, to continue their group work while becoming accustomed to digital tools and platforms, to ensure that the project work continued, and adapt to the abrupt global crisis. Upon students' request, one week was reassigned from Integration to Mitigation. From then on, all interactions on the course and group level happened on online platforms such as Teams and Discord. As a general observation, students missed the informal and personal aspects of academic life in this period.

The SALT program and SP4 prescribe a general notion of interdisciplinary education: Disciplinary boundaries exist but are blurred; students build personal trajectories based on basic knowledge; unique academic profiles come together in group work. In the next section, we elaborate on how we engaged in the specific setting to achieve insights, shifting around individual and group perspectives, and bouncing between group, team, and individual levels.

4. Research design

Given our exploratory goals and SP4's open, contextually rich group-work environment, we adopted a grounded theory approach to help draw forth patterns from the various processes and experiences in SP4, illustrating and making sense of the dynamics behind the variety and richness of responses to the educational context as we witnessed them. Most importantly, we appealed to the exploratory power of grounded theory to "understand the process by which actors construct meaning out of intersubjective experience" and "make knowledge claims about how individual interpret reality" (Suddaby, 2006, p. 634) in the less familiar and less clear-cut LAS contexts. In practice, the occurrence of interdisciplinary learning tends to be black-boxed. It is assumed to emerge naturally and directly as the output when inputs from different disciplines are brought together. The often obscured coming-into-being and the implicit, tacit dynamics of interdisciplinary education encourage the use of grounded theory to gradually develop, refine and interrelate concepts, and to understand the contextual and interactional factors that shape how and when events are perceived as interdisciplinary.

Our analysis followed grounded theory's key principles of constant comparison and theoretical sampling (Glaser & Strauss, 1967). By comparing similarities and differences between and among groups that are ongoingly included, we achieved diverse conceptual categories and properties as well as generalized relations among them. Meanwhile, the "process of data collection is *controlled* by the emerging theory" (p. 45); thus, new data unfolded simultaneously with our analysis and theory building along the course of research.

While a purely inductive approach avoids theoretical and definitive presuppositions, abductive reasoning was indispensable for inferring concepts from raw data and directing upcoming data collection (Gilgun, 2019). Further sensitizing concepts served as "a place to start inquiry, … departure for developing, rather than limiting, our ideas" (Charmaz, 2014, p. 31), gave "a general sense of reference guidance in approaching empirical instances" (Blumer, 1954, p. 7), and drew "attention to important features of social interaction and provide[d] guidelines for research in specific settings" (Bowen, 2006, p. 14). In our case, initial, tentative, and broad notions such as student academic identity, program identity, and interdisciplinary experience were such concepts, with which we could orient ourselves in broad LAS settings to become familiar with and collect personal remarks and interpersonal practices from the research field – particularly (online) meeting rooms where students gathered and interdisciplinary learning was assumed to occur.

Data collection started in February 2020 with observations by the first author of class meetings in which students formed groups and chose topics as well as group meetings in which students mapped and modeled their projects and formed small expert teams. When the educational practices were affected by the COVID-19 restrictions, observation continued online. Expert teams coordinated their work within their groups. We also contacted informant students for updates on progress in the groups. Fieldnotes based on observation (33.5 h) and online talks with informants (2.5 h) were used for developing sensitizing concepts as well as an interview protocol.

Towards the end of SP4, we contacted all 48 students for voluntary participation in individual interviews. The first author conducted in-depth semi-structured online interviews with 25 students. On average, each interview lasted one hour. In the interviews,

Table 1
Distribution of interviewees (right-hand column) over the groups.

Large groups	Expert teams	Group members interviewed
Group A	A1, Assessment of six emerging technologies	11, 21
Sustainable energy	A2, Energy storage solutions	15, 16
14 persons, leader *22*	A3, Sustainable energy business models	03, *22*
	A4, Social acceptance	08, 14
	A5, Coproduction of agriculture and solar energy	17
	A6, Energy conversion parks	20
	A7, Energy grids	07
Group B	B1, Consumerism	
Human trafficking	B2, Corruption	12, *25*
12 persons, leader *25*	B3, EU cooperation	04, 06
	B4, Recovery	09, 13, 19
Group C	C1, Public engagement	*23*
Pandemics	C2, Public health measures	01
12 persons, leader *23*	C3, Tracking	02, 18
	C4, Vaccine	05, 10, 24

students were invited to elaborate and reflect on their interdisciplinary learning experience in relation to their disciplinary identities and group work. All researchers in this study had an entirely independent position external to the course and the study program. Moreover, participating students were granted anonymity and confidentiality for the insights they offered. The interviews were guided by a protocol designed using sensitizing concepts and covering three main themes: perceived learning outcomes, disciplinary identity, and interdisciplinarity (see Appendix A). Students were asked to briefly introduce their activities in SP4 and then probed through conversations and encouraged to share detailed stories, examples, reflections, emotions, comparisons with previous experiences, and other forms of rich data. Participating students included three group leaders and members of all but one of the Mitigation expert teams (see Table 1 for the distribution of interviewees over groups). To ensure reliability and validity, interviews were transcribed and analyzed anonymously following the constant comparison principle. Interviews and transcripts were complemented and corroborated with fieldnotes and analysis of documents; specifically students' intermediate and final project reports. The research procedure, including access to observation sites, students and documents, was approved by the university's ethical committee.

In a follow-up meeting after the data analysis, the main findings were presented to two students and SP4's semester coordinator, who generally recognized and confirmed the patterns and categorization which emerged from the data. These methods led to detailed and thorough pictures of students' experiences in SP4, SALT, and education in general, as well as their perceptions of themselves as developing academics and as SALT members.

5. Results

Our analysis provides a substantive account of the construction and enactment of interdisciplinary learning in the collaborative LAS environment. By interweaving individual development and group-work dynamics, interdisciplinary learning manifests and takes shape through a variety of identities, experiences and tensions. The account starts with the sensitizing and conceptualizing of students' disciplinary identities, following the recognition of a tacit assumption in the SALT context: namely, the perceived dichotomy or opposition between social and technical people.

5.1. Configuring disciplinary identities in the interdisciplinary context

Our investigation revealed the role of disciplinary identity early on as a relevant sensitizing concept, which we further pursued in depth. As initial observations and informal conversations suggested, academic identities within SALT were positioned according to certain disciplinary frameworks, despite the program's interdisciplinary goal. This observation is best illustrated with an incident observed in the preparatory pressure-cooker session, in which students had to choose three topics from the brought-forward potential ones. Several candidate topics were crossed off, as they excluded students with certain disciplinary interests. Then one coordinator addressed the class: “So, the technical people raise their hands”. Seeing a response from around one-third of the students, he continued: “And the social people?” This time somewhere around half of the students reacted. “Who are half-half?” A few raised their hands (Fieldnote 2–7).

This instance stood out because LAS students are not supposed to be subject to any disciplinary labelling and mostly do not follow a specific disciplinary educational trajectory as in traditional programs. Interviews also revealed that students' academic interests often involved a combination of input from both what is considered as technical—involving machines, computation, and natural sciences—and what is classified as social—ranging from humanities such as history, philosophy and law to social, behavioral and management sciences. Therefore, the dichotomy of social versus technical cannot adequately capture one's disciplinary identity and, hence, is undoubtedly a simplification. By exploring how this simplification nonetheless made sense in SALT, we recognized that students do not develop disciplinary identities as a homogenous whole that complies with a universal pattern given the disciplinary structure of knowledge. We spotlighted the diversity in LAS students' disciplinary identities and discerned three general profiles among SALT students.

A majority of students acted as *disciplinary specialists* within interdisciplinary contexts. They devoted themselves to one particular disciplinary path and developed their in-depth expertise accordingly, in a domain that can be considered as either social or technical. However, they did not limit themselves strictly to disciplinary territory, but were keen on developing other disciplinary perspectives. As one student put it, SALT educates “engineers also with a social, not really vision, but like an understanding of social issues that you just don't have those bubbles where engineers do engineering things” (11). These students were often interested simultaneously in different subjects, one as their main academic focus and the others as auxiliary. For example, a student who introduced himself as dedicated to physics also mentioned his interests in philosophy, music, and society. Interdisciplinarity, for them, meant the indispensable context, consisting of a myriad of disciplinary elements, within which they developed their disciplinary specialization.

Some students explicitly saw themselves as *topic experts*, engaging with specific themes such as environment, sustainability, and policing. Their disciplinary identities could not be generalized as or defined by any one traditional discipline, but necessarily encompassed perspectives and expertise rooted in various disciplines. Therefore, they did not even develop academic profiles conforming to a social-technical divide. Instead, they chose electives that potentially connected to their subjects of interest, regardless of disciplinary tags. In one example, a student who described herself as interested in policing and aspired to eventually join the Dutch police, described herself as having “taken all kinds of courses, such as public and private policing, public safety, governance, psychology and crime… all the courses reflect[ing] on what the police is doing right, what the police is doing wrong, what can be improved…” (04). In such cases, students pursued certain topics or questions, and their academic identities in terms of discipline should be characterized as inherently interdisciplinary.

There were also students who could be profiled as *identity explorers*. They primarily expressed vagueness, hesitation and uncertainty

over disciplinary identities. When mentioning fields in which they took courses, their study activities within these fields were primarily motivated by interest, not (yet) by dedication. They were still in search of the latter: "I wasn't sure where to focus on, but I had certain interests in my guidelines" (12). These students lingered between different subjects, and showed ambivalent and undecided ambitions for their future development, which they often explained as their reason for joining SALT: "The reason why we join SALT is because we don't know what we want to do in our lives" (12). For identity explorers, interdisciplinarity was a willingness to taste different subjects and disciplines in the process of searching for a theme or subject, which they could devote themselves to and orient their choices of learning around.

SALT therefore gives students room to explore and take on variety of identities, beyond those ordinarily possible within a traditional program. The various identities are fundamentally interdisciplinary. Even in the case of disciplinary specialists, students defined their identities outwardly, with respect to their role in interdisciplinary work. The three profiles are not absolute demarcations between students, but indicate dynamic patterns of disciplinary identities within the program. The disciplinary specialists had a strong departure in one discipline, the topic experts transcended disciplinary structures, and the identity explorers were still searching for their academic dedication. For most SALT students, the exploration of identity was a pivotal consideration for joining the program: "When I started… I didn't know what to study because there were so many nice things and I just wanted to do everything" (08). Many students who now considered themselves as disciplinary specialists entered the program as identity explorers, before gradually developing more steady identities. Some completed this development just by the end of the fourth semester (including SP4). Students also mentioned peers who quit the program in the first year once they determined which academic directions to pursue, and joined other discipline-specific bachelor's programs, settling into specific disciplinary identities by detaching from SALT.

Recognizing LAS students' diverse disciplinary identities helps elucidate what the social-technical binary simplifies. Characterizing someone as social or technical may seem right for the conspicuous population of disciplinary specialists, but it overshadows identities that do not immediately align with the social-technical spectrum and blurs the important diversity among students. Moreover, the dichotomy presumes disciplinary identities to be steady, and bypasses the nuanced dynamics in how they manifest different aspects in different profiles. While the dichotomy admittedly helps reduce the myriad of academic profiles and facilitate creation of interdisciplinary groups, it overgeneralizes the subtleties of disciplinary identities and forces students, especially explorers, to fit the binary disciplinary model. Instead of developing uniformly, LAS students find meaningful interdisciplinary roles through a variety of identities and different ways of interpreting interdisciplinarity, which undoubtedly entail different journeys of development into interdisciplinary learning and call for differentiation in education.

5.2. Beyond disciplinarity: an interdisciplinary SALT identity

A rich general academic identity, closely bound to SALT's educational and social community, also emerged from our analysis. On the one hand, this general academic identity instantiated the program's educational ambition of preparing students for real-life interdisciplinary work; on the other, it exhibited value perceptions related to the program's distinctive educational ideal and institutional status. Both aspects foreground the overarching SALT academic and social culture, which plays a prominent role in students' responses to interdisciplinarity. The SALT identity is reinforced by the students' interdisciplinary development, but at the same time provides the safe and encouraging context in which students can explore and develop their academic identities.

The SALT identity itself has multiple dimensions. First, it is tied to shared disciplinary competencies. The program's first-year curriculum guarantees broad-ranging basic knowledge for graduates through compulsory courses covering different domains. All-round disciplinary basics often serve as common grounds in students' collaboration, allowing them to understand each other's disciplinary viewpoints and input. These understandings initiated connections, as a student described: "If I would work together with someone in physics and I would say, yeah, I've also taken a course on physics… then there's this better connection of people… if I would have never done some physics courses, they would be like, yeah, but you don't know what the hell you're talking about" (20). This capacity of appreciating and engaging multiple disciplinary perspectives, known as cognitive flexibility, prepared students as boundary agents who could "adapt in interdisciplinary problem spaces", meanwhile "leveraging boundary objects with their intersecting social worlds/meanings" (Nersessian & Newstetter, 2014, p. 726).

SALT also promotes connections between different disciplinary elements through self-directed learning. When structuring educational activities around their interests in particular electives, students developed affordances that embodied different disciplinary expertise. Students were thus not limited to certain disciplinary regimes, but more easily synthesized elements from different disciplines. For instance, one student, who had a zeal for environment studies and was often considered by peers as being on the social side, also studied physics and engineering, given the wide scope of environmental interests. Project work further helped students fuse their acquired multiple epistemological lenses: "I kind of used the projects, always as a way to really learn about this energy transition and climate change" (07). As such, students' disciplinary identities went beyond flexibility and became multifocal: Their different disciplinary foci merged into coherence, which allowed them to shift fluidly between disciplinary approaches and characterize themselves as transcending disciplinary boundaries.

Furthermore, generic competencies, sometimes mentioned as transferable or soft skills, also characterize the SALT identity. Fostered through project-based learning, such competencies particularly concern teamwork, communication, project management, and leadership. Students often addressed such development by mentioning specific learning outcomes, such as taking initiatives, having clear overviews, taking certain team roles, and communicating effectively. Some even explicitly expressed their core academic identities as mediating among disciplinary experts and coordinating different input: "[R]ather than a lot of people who either have some focus, either like in law or in governance policy or sustainability, whatever, I don't know, my focus in and of itself was also the integrative aspect" (25); "It's not my expertise to do research, write a report myself and have a recommendation or anything, but better

the interaction with people and in it, working together in a group towards a common goal" (10). For such students, self-identification as an all-around problem-solving coordinator surpassed disciplinary foci and characterized their academic identities.

SALT-related competencies, disciplinary and generic, were coupled with attitudes that echoed its values about diversity, collaboration, and interdisciplinarity. One attitude often mentioned and alluded to was "openness". This attitude is firstly content-oriented. Students tended to notice and welcome different inputs from different personal, cultural, and disciplinary perspectives. The appreciation of different backgrounds stimulated discoveries such as "…one idea from my home country, which we thought would be part of the mitigation strategy" (12), broke "those [disciplinary] bubbles where engineers do engineering things" (11), and underlined the value of integration in the constantly emphasized interdisciplinary approach. Secondly, students are open towards project-based group-work structures. This openness referred to beliefs in the advantage and necessity of professionals from different disciplines working together, which is frequently portrayed in society as the norm and reality in students' future careers. SALT settings, especially SPs, familiarized students with and adjust them to the "labor market and career in the future … [where is] a constant increase in interdisciplinary teams" (10); simultaneously, these settings conveyed such beliefs and attitudes.

Yet another attitude was constantly voiced among interviewees in their self-identification and how they made sense of their learning experiences and SALT peers. When discussing experiences of failure or inadequacy, students primarily expressed a common sense of acceptance, trying to justify these experiences from a positive, constructive, and developmental point of view, as "still a learning process and you always gain something" (11), "still educational" (23), and "it's like how it would be in real work" (03). Such views were described as a SALT mindset that makes its students stand out: "That's how students in SALT think" (23). This collective identification characterized SALT students, who "are very driven, very enthusiastic and are not being the typical 9 to 5 type students… They're not afraid to fail" (19) and "everyone is generally doing their best work and putting more into everything" (06). Therefore, this symbolic aspect of SALT identity was strongly intertwined with emotions, evidencing ambition, resolution, and pride. Students' appreciation of and affiliation with SALT and its values communicated the sense of being privileged and distinguished, which signified SALT's special status in the university in terms of its organizational structure and educational philosophy, together with its own building, unique staff constellation, high-standards selection-based admission conditions, and particularly close bonds among students.

In addition to describing this SALT identity and how the program setup promotes it, it is worth noticing that this identity is not essentially embodied in the program itself, and transferred one-sidedly from the program to its students. Instead, SALT identity is formed through mutual selection and construction between students and the program setting. Not only does the program cultivate and educate students into this interdisciplinary, group-work-favoring identity, students with interests in multiple domains and inclination towards working in project-based groups actively chose this very program and shaped the SALT identity. By joining this LAS program, students defied disciplinary learning approaches and sought out eclecticism or integration in education. For example, one student who favored data science explained his reason for joining SALT: "I cannot, necessarily, delve immediately very deep into that [data science] and then come out and be like 'Oh, well, now that I know that'... But I want to be the one to link to different types of disciplines" (18). This striving towards interdisciplinary learning was often voiced with preferences for hands-on experience and social engagement, against the individual-oriented, knowledge-based traditional education: "SALT students are more people who like to do projects rather than exams" (12). Therefore, students rationalized their LAS endeavor in reflections as "just learning about more other things than my expertise has always been very interesting to me …[and] learning about other perspectives and combining those and finding a way to talk to multiple people and learn about what they're doing" (21), and "I'm not saying that I refuse technical parts, I just don't want the [technical] program. I just don't want a programming job. I also want something that I handle people or I work with [people]" (01).

SALT identity and the belongingness are built and maintained by the official program settings, but also in informal social environments—the SALT study association, housing environments, and after-school activities. Students emphasized how the sense of community contributed to the formal learning activities, highlighting reasonable expectations of each other, positive atmospheres, and interpersonal relationships:

> [T]he main thing that helped [group work] is that we know each other already and we are actually all good friends as well… In the beginning of the meeting, we would often joke around a bit and just share experiences… I already kind of knew their expertise, which then also really helped to, um, easier understand what contributions everyone could make because we already know each other quite well. (10)

SALT's social dimensions offer students a comfortable environment for learning and intellectual development. As students clarified, "group bonding activities", were

> …simply little social events that were organized… just to relax with each other… make it easier to work with [others]… [W]hen you're more friendly with people, it's just a little bit easier to work with them and you're less afraid of confrontation and such, because it's not arguing with a stranger. It's just voicing your concerns to someone that you know will understand and listen. And obviously, SALT has a big focus on community. (17)

Diverse SALT students were, therefore, united to an extent by the SALT identity which fosters broad disciplinary and generic competencies, values different perspectives and project work, and furthermore promotes group work and interdisciplinarity. Just as disciplinary identities rely on collective disciplinary emotions (Salmela & Mäki, 2017), SALT identity is linked with emotions, values and a sense of belongingness to the community. SALT students, responding to the interdisciplinary context, grow at the intersection between their self-configured disciplinary identities and the general SALT identity. Through our engagement with SP4, we observed that interdisciplinary learning in group work corresponded to social dynamics of interactions and transactions between and among different intersectional academic identities, in which contending and compromising disciplinary identities, as well as the mediating

and uniting SALT identity, intertwine.

5.3. Identities in action: how interdisciplinary learning emerged as experience

Our account so far has discussed identities in the SALT interdisciplinary context. When different identities acted, interacted and transacted in the highly interactive SP4 learning environment, group work dynamics were constituted, bringing about different experiences of interdisciplinary learning. Our account in this section therefore parallels interdisciplinary experiences and group-work dynamics in which students' academic identities manifest, communicating, contending, negotiating and unavoidably compromising with each other, constantly undergoing modification and mediation. We discuss here how interrelating identities constructed and enacted interdisciplinary experiences in the group work, based on our observations and students' perceptions and interpretations of their experiences.

Students' retrospective accounts overall suggested that the interdisciplinary experiences varied, both vertically through time and horizontally across individuals. Vertically, SP4's three phases triggered different experiences. Horizontally, although students perceived the first phase similarly, as well as the third, their group-work experiences diverged greatly in their smaller expert teams during the in-between Mitigation phase. We concentrated our analysis on the Mitigation phase, so as to compare across the different experiences and grasp the patterns behind the variety. Students, not only the typical disciplinary specialists but also topic experts and identity explorers, all assumed certain disciplinary positions within a social-technical binary frame in their accounts of SP4 interdisciplinary experiences, which thus presupposed disciplinarity as a basic framework for orientation and self-identification. Different experiences were clustered into three patterns, best understood as different facets of the learning experience: They coexisted, but could dominate students' perception at different moments, even though some interview accounts could be rather easily categorized as matching one of them.

The first, a *non-disciplinary experience*, indicates a shallow, basic academic experience. Accounts here primarily revealed a sense of unfulfillment regarding compromises students made during group work, voluntarily or unwillingly. This shallowness was revealed in reflections such as “I wouldn't want to say anyone can do it, but it's more like, it doesn't belong to a specific skill” and you “don't need too much expertise for it” (02). This comment was made by a student whose expert team hoped to practice specialties that would have required substantial preparatory work from other teams in the group. His team ended up reading and summarizing articles, and he felt unable to exert his expertise. Similar feelings of merely doing basic academic tasks and drifting on the surface of insights also appeared within expert teams that strived hard for common grounds. To reconcile different disciplinary perspectives, members struggled with preparing and defining the steps of their research, which took over their disciplinary endeavors. As a result, they could barely explore their disciplinary ambitions given the limited time but staggered along on mostly trivial, general problem-solving tasks. Without disciplinary engagement, “it's just more about Googling” (04) and students found themselves, and sometimes each other, stuck in shallowness.

The second pattern, which we call a *monodisciplinary experience*, describes thoroughgoing engagement in one's interest and expertise, while lacking meaningful integration beyond the very discipline or interaction with dissimilar-minded peers. One side of this experience was discipline-based enthusiasm and dedication, since SP4, unlike previous SPs with prescribed topics, gives students considerable room to define research topics and shape the project following their disciplinary interests. SP4 “definitely gave me the opportunity to kind of see how I can contribute to a project with my expertise” (03) and therefore met students' disciplinary expectations. For many, this disciplinary homogeneity was pleasant: “[I] worked with someone who had the same interests, which for me was brilliant… [It's] academically interesting to do a project with people that are actually interested in the same things” (16). But the disciplinary opportunity came with trade-offs. The same students also noted that they missed the feeling of being interdisciplinary, which they experienced as a limitation. Students might actively seek connections outside their homogeneous teams, but being aware of other teams' work and perspectives did not often generate meaningful results. The response to a proposal from a student to link her own business perspective with another team's work on a socio-technical innovation was “that's not exactly what we're doing” (03). Recognizing social aspects of emerging energy-generating technologies also did not result in interaction with another team working on social acceptance: “I really didn't communicate with them at all... [I]n hindsight, yeah, I probably should have. But on the other hand, … most of my thing isn't focused on social things” (11). The missing links with other disciplinary input sometimes resulted in a sense of mono-disciplinarity, being intellectually limited within one disciplinary domain and emotionally feeling lonesome, not even understood or cared about: “just working on the side on my own…didn't really get to be part of [group]. It was just me performing my expertise and applying it to [the topic]” (03).

The third pattern, *interdisciplinary experience*, pictures how interdisciplinarity was perceived as genuine and authentic. Primarily, this perception entailed appreciatory recognitions of both one's own contribution and intellectual interaction between members, which relied on and reinforced each other:

> … I was super dependent on my peers in order to do meaningful research, whereas if I would have done this all alone, I don't think I could have reached the same things… just because that would be so much more biology I would first need to read into before I can work on my own topic… We wanted to create a small platform for researchers in order to facilitate collaboration, but also the coordination of the collaboration which is known by the platform itself using AI. And I think… my own input was really useful because for the platform itself, AI was the backbone of this, which was my discipline… (05)

This twofold recognition shows how input from other disciplines helped students practice and achieve their own disciplinary ambitions and development, which in turn benefited the collective group work. Connecting and reconciling different perspectives was crucial in attaining recognition, and was often realized by members translating deep disciplinary knowledge into intelligible common

knowledge, neutralizing abstruse professional terminologies and concepts so everyone understood. This translation and understanding created common ground for meaningful connections between pieces of input, based on which agreements were reached regarding definition and operationalization of the problem as well as distribution, organization and alignment of tasks. Furthermore, the interdisciplinary experience was also characterized as "energy giving instead of energy draining" (10), featuring recurring remarks that referred to good communication and a pleasant atmosphere. No "dominant or strong personalities… think[ing] that their ideas are way more important than other people's ideas" (19) guided group dynamics, but there was instead a sense of friendship and interpersonal engagement. Therefore, interdisciplinarity was perceived as a shared positive learning experience that challenges established disciplinary boundaries, in both cognitive and sociocultural dimensions.

Comparing the three patterns helps distill two key elements central to interpreting experiences as interdisciplinary. Primarily, "feeling interdisciplinary" presupposes a degree of disciplinarity and requires *disciplinary enablement* – the ability to apply one's disciplinary expertise in the setting. Students orient themselves in open-ended learning environments by seeking recognition of and undertaking disciplinary approaches where they see mastery, interest, and commitment. Fruitful interdisciplinary experiences therefore require this enablement, the absence of which can shape perceptions of work as superficial and over-general, lacking profoundness and meaningfulness. These attitudes reflect a common criticism that ascribes interdisciplinarity as shallow, surface sciences (Frodeman et al., 2001). The open-structured LAS context creates possibilities and has consequences for disciplinary enablement. First, SALT's broad disciplinary competencies and multifocal epistemological lenses unbind students from the constraints entailed by rigid, well-defined disciplines, thus allowing disciplinary enablement to transcend specialized disciplinary conventions and contexts. Second, when individual identities each demand disciplinary enablement in actual group work, pleas for group-work coherence inevitably balance competing disciplinary identities through finding common ground, compromises and tradeoffs. When students' expectations of practicing disciplinarity, as SP4 promises, fails, group-work engagement can be undermined and students' own disciplinary growth hampered.

Moreover, interdisciplinary group work requires *disciplinary transaction*, where enabled disciplinarity is no longer an individual matter, but transforms from a personal specialization into interpersonal intelligibility, becoming common ground for the group work. Rather than a one-sided transfer or monologue, this transaction is a mutual and reciprocal process of sending and receiving across disciplinary identities. It is only fulfilled through teammates' understanding and recognition of one's own disciplinary contribution. Disciplinary transaction varying in levels of depth, meaningfulness and effectiveness characterizes the interdisciplinary experience.

These two key elements are interrelated and interacting. First, disciplinary enablement may constrain transactions. Students whose disciplinary dedication is so strongly enabled may perceive their disciplinary identities to be reinforced and their specialized expertise as private and exclusive. For example, one student expressed her frustration at "working with maybe someone who isn't as business-oriented as I am. It was very hard to explain methods in social science and research, so, like why there are certain rules to do a proper literature review, for example… Because these are the rules of empirical research. You can't just neglect that" (03). She defended rigid discipline-specific epistemologies and methodologies out of loyalty to disciplinary norms and values, applying an "us-them" narrative to distance herself from peers perceived as less disciplinarily engaged or competent. Accordingly, transactions, and even reconciliations with others, become deliberately or unconsciously rejected. Second, disciplinary transaction can feed back disciplinary identities by strengthening and developing disciplinary foundations. Disciplinarily transactional practices such as teaching, learning, and instruction among peers, which were often observed in SP4. These activities facilitated the exercise of students' disciplinary expertise, potentially resulting in broadening one's disciplinary identity or recognizing latent disciplinarity-enabling possibilities.

Illustrating interdisciplinary learning as action, interaction, and transaction of individual academic identities in group-work dynamics brings insights into how it was constructed and enacted in this LAS environment. The complexity of academic identities—intersecting disciplinary identities and SALT identity—further triggered tensions, regarding both SP4 work specifically and, in a broader sense, LAS students' long-term academic development. These tensions, as we discuss next, signify important challenges for interdisciplinary education and interdisciplinarity in general.

5.4. Interdisciplinarity and tensions in LAS education

While LAS education aims to assist students' development of their own academic identities and trajectories through the overall program identity, our study suggests that students do not always experience or perceive the self-learning goals, interdisciplinary learning goals, and incentives that create space for developing their identities as necessarily coherent. When LAS students are constructing interdisciplinary experiences, their intersectional academic identities are simultaneously shaped, undergoing and growing from challenges encountered in the environment. Therefore, understanding interdisciplinary education in LAS contexts requires noting the difficulties and struggles LAS students face when striving for interdisciplinarity.

In the first place, we saw tension in the project work concerning how students perceived and acquired their roles. Students sometimes sense conflicts between working as disciplinary specialists and SALT's orientation towards general, overarching perspectives. Disciplinary specialty "is like an expertise, but that's hard to apply most of the time… because it's way too detailed. And in these projects, you design a solution most[ly], but most of the time that means you have a little bit more of a bird's eye view of the problem" (02). The comprehensive overview required by project work in SALT therefore sometimes blurred the specialized disciplinary endeavors that students hoped for and were expected to develop.

Other tensions emerged at the organizational and institutional levels. For instance, the electives on offer, while broad, were mostly disciplinary and organized by particular faculties with distinctive disciplinary identities. Thus, "from electives there are people from more technical side and from more social side" (Fieldnote 2–11), which served to reinforce these identities, and students were induced to diverge disciplinarily. Furthermore, SALT students often presupposed a disciplinary framework, especially when considering next-

step academic pursuits, partly because graduate education largely remains itself disciplinary. Students were thus pushed to develop specialized, concrete academic profiles because "I'm kind of worried that, if I don't go specific enough, that when I apply for a master's program, that I don't meet the requirements…" (18). Sometimes they narrowed their choices of electives to only one particular discipline to collect enough credits to meet admissions requirements: "[I] could have done the [other] bachelor and done most of the [same] courses" (02). The interdisciplinary value of LAS and future disciplinary demands were thus perceived as contradictory, as one student worried – "a lot of courses I've taken that are not necessarily relevant towards anything I'm doing [later]… I need to meet the EC [credit] requirements of the new master's program, and that sometimes gets hurt by being interdisciplinary" (18). Therefore, once students have embraced a clear disciplinary trajectory and identity, the SALT identity's broad view and interdisciplinary openness can easily appear to lose their value and importance.

This tension was also symbolized in, and manifested as, emotions towards the SALT community, where students lived, learned, entertained, and had social activities largely together. Their educational experiences and private lives were largely entangled and even merged. Separating the two could be difficult and sometimes required rules such as "when we're not working on the project, don't talk about it" to "not get into fights in real life" (16). The intense social interaction and cohesion within the community, especially bound to SALT's student association, was sometimes described as "exclusive", "obsessive" and "overwhelming" (16), and could engender a feeling of lacking social integration outside of the community. As one student put it, SALT is "like having a family always with you. And sometimes you just want your own time" (12). Furthermore, although students mentioned how close social connections contributed to their SP4 group work, they did encounter difficulties adapting to each other's work styles in earlier SPs. The wisdom of optimizing group work and avoiding incompatible peers was not intrinsic to SALT, but was developed through a long period of trial and error.

Tensions emerged at the bridge between distinctive disciplinary identities and the overall LAS-based, group-work-oriented SALT identity: One requires expertise, particularity and professionalization, while the other requires integration, integrity and appeal for the general public. The two represent two dimensions of knowledge work – specialization and integration – that need reconciliation but often conflicted in students' intersectional academic identities. The social-technical simplification can be regarded as a response to this tension: By prioritizing disciplinarity as familiar to the university and the society, the binary division orients students' further academic development. As a tradeoff, it may overlook individuals' interdisciplinary characteristics and oversimplify interdisciplinarity as a principle for group work.

6. Discussion

Our analyses give a rich account of how students experienced and oriented themselves with respect to interdisciplinary learning within a LAS learning environment, and as a result, of how interdisciplinary education was constructed and enacted within the LAS context. These results raise issues for both the theoretical understanding of identity in interdisciplinary learning, and educational practices directed towards training interdisciplinarity.

6.1. Theoretical significance: identities in LAS education

In the first place, our results re-emphasize the importance of the intricate attachment and mediation between identity development and learning environments (Collett, 2020; Nasir & Cooks, 2009), but point to more complex ways in which identities develop. Researchers have argued that "design of formal learning environments should focus on surfacing, recognizing, and supporting disciplinary interests and identities" (Van Horne & Bell, 2017, p. 472). However, which disciplinary identities are or should be cultivated in interdisciplinary LAS programs, in which students are expected to form unique learning trajectories that cross disciplines? This question echoes a more general one: "If the discipline is the locus of academic identity, from where does an interdisciplinary scholar draw their sense of self?" (Lange, 2019, p. 2). We showed how SALT handles this issue through the cultivation of multiple identities: a SALT identity and SALT students' academic identities. Because "there are no learning environments or experiences that are neutral to identification" (Bell et al., 2017, p. 368), through its program setup and social environment, SALT fosters a general academic identity involving expertise and attitudes that promote interdisciplinary learning. Identity in this respect is treated as an explicit resource or educational tool that can be cultivated for specific purposes. In addition, using intersectionality as a broad analytic tool (Marfelt, 2016) helps unravel the complexity of students' academic development and personal growth. Not only disciplinary identities, but the interdisciplinary SALT identity and the aggregate of the two are "at the intersection of social structures, disciplinary norms and practices, and youths' identities" (Carlone, 2017, p. 527).

Analyses of LAS students' academic identities let us identify the key elements for interdisciplinary experiences in group work, namely disciplinary enablement and transaction, which corresponds to an intuitive understanding of "interdisciplinarity", considering its etymology and literal meaning (Alvargonzález, 2011). Other empirical studies have drawn similar observations concerning other group-work settings. For example, in healthcare professional environments, Hall and Weaver (2001) identify specialized professionality and professional collaboration as two conditions of effective teamwork. Yet, deriving these two concepts specifically from the LAS setting is valuable, particularly because LAS students are far from professionals with relatively stable, clear-cut disciplinary identities. Our study suggests as such the possibility of a universal logic for interdisciplinary collaboration, one corresponding to specialization and integration of knowledge work, that could facilitate the design of interdisciplinary environments in different contexts.

6.2. Practical significance: identity of LAS education

As we illustrated, LAS environments trigger complex sets of responses from students in terms of identity development and learning experiences. Their responses, sometimes experienced as tensions, have implications for LAS educational practices and goals. Tensions that confront LAS students are not merely individual or (inter-)personal matters, but reveal structural conflicts that LAS education inevitably confronts, between its interdisciplinary, integrative ideal of education and the prevailing specialized, fragmented disciplinary structure in the broad academic, institutional and social culture. Therefore, our analysis of disciplinary and interdisciplinary identities in LAS contexts also spotlights the identity of LAS education itself.

LAS programs such as SALT often aim to integrate multiple learning objectives, emphasizing both the specializing and the generalizing dimensions of knowledge work. However, the two dimensions are not easily balanced. Interacting with and adapting to the disciplinary structure of its home university as well as the disciplinary culture in academia and the broader society, SALT has tacitly bred and acknowledged the use of a social-technical binary to make sense of students' disciplinary identity, implicitly accepting and driving students to fit the prevailing disciplinary framework. The implicit disciplinarity reinforces the tensions students perceive, because it clashes with the promise and ideal of LAS education: namely, the dimension of integration in knowledge work and the attempt to create optimal conditions for self-learning, under which students can develop interdisciplinary expertise that suits their interests and motivations. It poses a question to LAS educators: Is LAS defying disciplinarity or just postponing disciplinary specialization, resembling an extension of high school?

In its defense, LAS education is not isolated from broader university systems and social-academic contexts. Since disciplinary fragmentation is not easily transcended by the relatively few LAS programs like SALT, such programs inevitably seek leeway for students to develop academic identities that are meaningful outside the program. Nevertheless, it is disputable whether such identities must conform with the established disciplinarity. LAS education could challenge and transcend the disciplinary culture. To achieve that, LAS education needs to recognize and acknowledge the tensions in which it is embedded. And educators, when conceiving, designing and implementing LAS practices, ought to agree on and communicate consistently about how they identify LAS education, as well as how much they depend on disciplinary university systems and embrace disciplinarity.

6.3. Implications for interdisciplinary education

For education that strives for interdisciplinary development, our findings underline the view that promoting interdisciplinary learning entails much more than just including content from different disciplines in curricula or integrating disciplinary angles into problem- or project-based learning. Developing interdisciplinary education inevitably involves balancing between two valued principles: granting students freedom in shaping their identities while crossing disciplinary boundaries versus ensuring students gain genuine and meaningful interdisciplinary experiences. The three types of profiles in identity development within the interdisciplinary environment—disciplinary specialists, topic experts and identity explorers—can be helpful in designing and evaluating differentiated interdisciplinary experiences. For disciplinary specialists, it is crucial that they are actively engaged in relating their disciplinary perspectives to insights rooted from different disciplines. Topic experts need to be able to incorporate different disciplinary knowledge and methods in their work, and ultimately transcend the disciplinary paradigms. And for identity explorers, it is important to be confronted with a broad and balanced range of possible disciplinary angles.

7. Conclusion and further research

In this study, we explored how students engage with interdisciplinarity and respond to interdisciplinary problem-solving environments within LAS environments, in which students can choose courses to tailor their own learning trajectories, trespassing across traditional disciplinary boundaries. Our results showed that students develop various and intersectional identities to reconcile the complex and often competing learning goals and objectives. Students' entangle academic identities, by interacting in specific educational settings, brought about different experiences in relation to interdisciplinary learning. In positive terms, the substantial, though not absolute, LAS freedom—stressing personal striving, self-determination, self-fulfillment, and empowerment—supported interdisciplinary engagement, help students take a certain level of control over developing their own individual standpoints towards interdisciplinarity, and ultimately promoted personal interdisciplinary skills and an overall attitude favoring interdisciplinarity.

However, the two key elements for authentic and fruitful interdisciplinary experiences—disciplinary enablement and transaction—represent two contesting dimensions of knowledge work that inherently embody tensions, as seen ubiquitously in LAS environments that have continual emphases on interdisciplinarity. When fast-growing LAS programs strive to combat extreme specialization in traditional educational regimes, we see that LAS education simultaneously needs to reconcile itself with a largely disciplinary educational-social regime and heed students' diverse disciplinary identities, embedding it within the holistic, integrated, interdisciplinary, and complex world.

There are however some limitations that have to be taken into account when interpreting our findings. The first limitation is that the data were collected on in-depth analyses of a specific course in one particular LAS program. It would be valuable to investigate academic identity formation and learning experiences in other interdisciplinary settings as well. Longitudinal analyses of academic identity formation from the very beginning to the completion of inherently interdisciplinary programs could further enhance our understanding of these processes. Although we managed to collect detailed data about the interdisciplinary nature of the course, our research design was affected by the COVID-19 pandemic, which complicated the communication between students as well as the data collection. Full-fledged ethnographic research involving even more profound observations and informal talks could have further

enriched our findings. Future studies could operationalize and investigate concepts such as disciplinary identity, disciplinary enablement, and disciplinary transaction in order to further our understanding of different interdisciplinary learning contexts.

Statements and declarations

This study was funded by 4TU.Center for Engineering Education, the Netherlands. The authors have no competing interests to declare that are relevant to the content of this article. The study has been approved by ethics committee of the University of Twente. All interviews conducted were based on informed consent of participants. The educational program studied in our case is pseudonymized for review.

Data availability

The data that has been used is confidential.

Acknowledgement

The authors thank the educators and students involved in the SALT program for their interest and participation in our study. We would also like to thank the Dutch 4TU.CEE (Centre for Engineering Education) for funding this study and the Comenius STRIPES project (Structuring Interdisciplinary Projects for Engineering Students) for its help in identifying the SALT program as a case for our research. We also thank prof. Kim Schildkamp, prof. Mieke Boon and other colleagues for their useful feedback on our earlier drafts. Finally we want to thank the three anonymous reviewers for their assistance in improving this article.

Appendix A. Interview protocol

The interview protocol used for this article can be found online at https://doi.org/10.1016/j.lcsi.2023.100716.

References

Alvargonzález, D. (2011). Multidisciplinarity, interdisciplinarity, transdisciplinarity, and the sciences. *International Studies in the Philosophy of Science, 25*(4), 387–403. https://doi.org/10.1080/02698595.2011.623366

Baker, V. L., & Lattuca, L. R. (2010). Developmental networks and learning: Toward an interdisciplinary perspective on identity development during doctoral study. *Studies in Higher Education, 35*(7), 807–827. https://doi.org/10.1080/03075070903501887

Becker, J. (2015). Liberal arts and sciences education: Responding to the challenges of the XXIst century. *Educational Studies*, (4), 33–61.

Bell, P., Van Horne, K., & Cheng, B. H. (2017). Designing learning environments for equitable disciplinary identification. *Journal of the Learning Sciences, 26*(3), 367–375. https://doi.org/10.1080/10508406.2017.1336021

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 83*(2), 39–43. https://doi.org/10.1080/00098650903505415

Blumer, H. (1954). What is wrong with social theory? *American Sociological Review, 19*(1), 3–10. https://doi.org/10.2307/2088165

Bog, D. K., & Van der Wende, M. (2016). Liberal arts and sciences education for the 21st century knowledge economy: A case study of Amsterdam University College, the Netherlands. In I. Jung, et al. (Eds.), *Liberal arts education and colleges in East Asia* (pp. 113–124). Springer.

Bowen, G. A. (2006). Grounded theory and sensitizing concepts. *International Journal of Qualitative Methods, 5*(3), 12–23. https://doi.org/10.1177/160940690600500304

Carlone, H. B. (2017). Disciplinary identity as analytic construct and design goal: Making learning sciences matter. *Journal of the Learning Sciences, 26*(3), 525–531. https://doi.org/10.1080/10508406.2017.1336026

Charmaz, K. (2014). *Constructing grounded theory*. Sage.

Choi, B. C. K., & Pak, A. W. P. (2006). Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. Definitions, objectives, and evidence of effectiveness. *Clinical and Investigative Medicine, 29*(6), 351–364.

Claus, A. M., & Wiese, B. S. (2019). Development and test of a model of interdisciplinary competencies. *European Journal of Work and Organizational Psychology, 28*(2), 191–205. https://doi.org/10.1080/1359432X.2019.1567491

Collett, J. (2020). Researching the complex nature of identity and learning: Positioning, agency, and context in learners' identities. *International Journal of Qualitative Studies in Education, 33*(5), 524–548. https://doi.org/10.1080/09518398.2019.1687955

Costa, A. R., Ferreira, M., Barata, A., Viterbo, C., Rodrigues, J. S., & Magalhães, J. (2019). Impact of interdisciplinary learning on the development of engineering students' skills. *European Journal of Engineering Education, 44*(4), 589–601. https://doi.org/10.1080/03043797.2018.1523135

Frodeman, R., Mitcham, C., & Sacks, A. B. (2001). Questioning interdisciplinarity. *Science, Technology, and Society Newsletter, 126*(127), 1–5.

Gee, J. P. (2000). Identity as an analytic lens for research in education. *Review of Research in Education, 25*(1), 99–125. https://doi.org/10.3102/0091732X025001099

Geschwind, L., & Melin, G. (2016). Stronger disciplinary identities in multidisciplinary research schools. *Studies in Continuing Education, 38*(1), 16–28. https://doi.org/10.1080/0158037X.2014.1000848

Gilgun, J. F. (2019). Deductive qualitative analysis and grounded theory: Sensitizing concepts and hypothesis-testing. In A. Bryant, & K. Charmaz (Eds.), *The SAGE handbook of current developments in grounded theory* (pp. 107–122). Sage.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research.* Adline De Gruyter.

Hall, P., & Weaver, L. (2001). Interdisciplinary education and teamwork: A long and winding road. *Medical Education, 35*(9), 867–875. https://doi.org/10.1046/j.1365-2923.2001.00919.x

Holley, K. A. (2015). Doctoral education and the development of an interdisciplinary identity. *Innovations in Education and Teaching International, 52*(6), 642–652. https://doi.org/10.1080/14703297.2013.847796

Huutoniemi, K., Klein, J. T., Bruun, H., & Hukkinen, J. (2010). Analyzing interdisciplinarity: Typology and indicators. *Research Policy, 39*(1), 79–88. https://doi.org/10.1016/j.respol.2009.09.011

Klein, J. T. (2006). A platform for a shared discourse of interdisciplinary education. *JSSE-Journal of Social Science Education, 5*(4), 10–18.

Klein, J. T. (2010). A taxonomy of interdisciplinarity. In R. Frodeman (Ed.), *The Oxford handbook of interdisciplinarity* (pp. 15–30). Oxford University Press.

Kovačević, M. (2022). The effect of a general versus narrow undergraduate curriculum on graduate specialization: The case of a Dutch liberal arts college. *The Curriculum Journal, 33*, 618–635. https://doi.org/10.1002/curj.158

Land, R. (2012). Crossing tribal boundaries: Interdisciplinarity as a threshold concept. In P. Trowler, M. Saunders, & V. Bamber (Eds.), *Tribes and territories in the 21st century. Rethinking the significance of disciplines in higher education* (pp. 175–185). Routledge.

Lange, M. A. (2019). What is the identity of interdisciplinarity? *Journal of Interdisciplinary Studies in Education, 8*(1), 1–5.

Lattuca, L. R., Knight, D., & Bergom, I. (2013). Developing a measure of interdisciplinary competence. *International Journal of Engineering Education, 29*(3), 726–739.

Lattuca, L. R., Knight, D., Seifert, T. A., Reason, R. D., & Liu, Q. (2017). Examining the impact of interdisciplinary programs on student learning. *Innovative Higher Education, 42*(4), 337–353. https://doi.org/10.1007/s10755-017-9393-z

Lindvig, K. (2022). Loud and soft voices of interdisciplinarity in higher education. In T. Øland, et al. (Eds.), *Configurations of interdisciplinarity within education. Danish experiences in a global educational space* (pp. 94–118). Routledge.

Lingard, L., Schryer, C. F., Spafford, M. M., & Campbell, S. L. (2007). Negotiating the politics of identity in an interdisciplinary research team. *Qualitative Research, 7*(4), 501–519. https://doi.org/10.1177/1468794107082305

Marfelt, M. M. (2016). Grounded intersectionality: Key tensions, a methodological framework, and implications for diversity research. *Equality, Diversity and Inclusion: An International Journal, 35*(1), 31–47. https://doi.org/10.1108/EDI-05-2014-0034

McNair, L. D., Newswander, C., Boden, D., & Borrego, M. (2011). Student and faculty interdisciplinary identities in self-managed teams. *Journal of Engineering Education, 100*(2), 374–396. https://doi.org/10.1002/j.2168-9830.2011.tb00018.x

Nasir, N.i. S., & Cooks, J. (2009). Becoming a hurdler: How learning settings afford identities. *Anthropology & Education Quarterly, 40*(1), 41–61. https://doi.org/10.1111/j.1548-1492.2009.01027.x

Nersessian, N. J. (2019). Interdisciplinarities in action: Cognitive ethnography of bioengineering sciences research laboratories. *Perspectives on Science, 27*(4), 553–581. https://doi.org/10.1162/posc_a_00316

Nersessian, N. J., & Newstetter, W. C. (2014). Interdisciplinarity in engineering research and learning. In A. Johri, & B. M. Olds (Eds.), *Cambridge handbook of engineering education research* (pp. 713–730). Cambridge University Press.

Newell, W. H. (1990). Interdisciplinary curriculum development. *Issues in Interdisciplinary Studies, 8*, 69–86.

Osbeck, L. M., & Nersessian, N. J. (2010). Forms of positioning in interdisciplinary science practice and their epistemic effects. *Journal for the Theory of Social Behaviour, 40*(2), 136–161. https://doi.org/10.1111/j.1468-5914.2009.00430.x

Palincsar, A. S. (1998). Social constructivist perspectives on teaching and learning. *Annual Review of Psychology, 49*(1), 345–375. https://doi.org/10.1146/annurev.psych.49.1.345

Power, E. J., & Handley, J. (2019). A best-practice model for integrating interdisciplinarity into the higher education student experience. *Studies in Higher Education, 44*(3), 554–570. https://doi.org/10.1080/03075079.2017.1389876

Salmela, M., & Mäki, U. (2017). Disciplinary emotions in imperialistic interdisciplinarity. In U. Mäki, A. Walsh, & M. F. Pinto (Eds.), *Scientific imperialism: Exploring the boundaries of interdisciplinarity* (pp. 31–50). Routledge.

Sauzet, S. (2022). Interdisciplinarity in the university colleges.: Versions of interprofessional responsibility. In T. Øland, et al. (Eds.), *Configurations of interdisciplinarity within education. Danish experiences in a global educational space* (pp. 69–93). Routledge.

Sklad, M., Friedman, J., Park, E., & Oomen, B. (2016). 'Going Global': A qualitative and quantitative analysis of global citizenship education at a Dutch liberal arts and sciences college. *Higher Education, 72*(3), 323–340. https://doi.org/10.1007/s10734-015-9959-6

Spelt, E. J. H., Luning, P. A., van Boekel, M. A. J. S., & Mulder, M. (2017). A multidimensional approach to examine student interdisciplinary learning in science and engineering in higher education. *European Journal of Engineering Education, 42*(6), 761–774. https://doi.org/10.1080/03043797.2016.1224228

Suddaby, R. (2006). From the editors: What grounded theory is not. *Academy of Management Journal, 49*(4), 633–642. https://doi.org/10.5465/amj.2006.22083020

Tubbs, N. (2014). *Philosophy and modern liberal arts education: Freedom is to learn*. Palgrave Macmillan.

Turner, S. (2000). What are disciplines? And how is interdisciplinarity different. In P. Weingart, & N. Stehr (Eds.), *Practising interdisciplinarity* (pp. 46–65). University of Toronto Press.

Van den Beemt, A., MacLeod, M., Van der Veen, J., Van de Ven, A., Van Baalen, S., Klaassen, R., & Boon, M. (2020). Interdisciplinary engineering education: A review on vision, teaching, and support. *Journal of Engineering Education, 109*(3), 508–555. https://doi.org/10.1002/jee.20347

Van der Wende, M. (2011). The emergence of liberal arts and sciences education in Europe: A comparative perspective. *Higher Education Policy, 24*(2), 233–253. https://doi.org/10.1057/hep.2011.3

Van Horne, K., & Bell, P. (2017). Youth disciplinary identification during participation in contemporary project-based science investigations in school. *Journal of the Learning Sciences, 26*(3), 437–476. https://doi.org/10.1080/10508406.2017.1330689

Vignoles, V. L., Schwartz, S. J., & Luyckx, K. (2011). Toward an integrative view of identity. In S. J. Schwartz, K. Luyckx, & V. L. Vignoles (Eds.), *Handbook of identity theory and research* (pp. 1–27). Springer.

Vink, C., de Greef, L., Post, G., & Wenting, L. (2017). *Designing interdisciplinary education: A practical handbook for university teachers*. Amsterdam University Press.