

## Chapter 4

# Young Women's Identity Work in Relation to Physics at the Transition from School to Further Educational Pathways



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At the end of high school young people are expected to think about their further education and have to come to terms with their ideas about their professional future. The school-leaving certificate marks the end of this stage of education. It opens up certain educational pathways while blocking others. On completion of high school young people enter a transitional phase that offers socially established and institutionalised opportunities for studying and making career choices.

The importance of study and career choices of young people is twofold. They are central to an individual's life as the choices can influence how satisfied a person is with their life and what position he or she can take in society (e.g., welfare in terms of health, livelihood and socio-economic status). In this respect, educational decisions are closely linked to individual development opportunities. At the same time educational choices are of high relevance for the social and economic needs of a society. In Germany, there have been complaints for years about a shortage of labour, especially in technical and scientific occupations (Pohlmann & Möller, 2010). Furthermore, there is a need for a diversity of professionals, and questions of empowerment of under-represented groups can be raised that are closely related to issues of justice (Bøe et al., 2011).

In Germany – similar to other countries – there is the (perceived) societal need to attract more young people and especially women to study physics or to choose professions linked to physics. However, the number of young women participating in physics is only moderately increasing, drop-out numbers at universities in Germany are large (Heublein & Schmelzer, 2018) and women continue to be under-represented (for instance, twice as many male as female first-year students enrolled in physics in Germany in 2018; Statistisches Bundesamt, 2019).

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Thus, decisions about educational pathways in science, technology, engineering and mathematics (STEM), and specifically in physics, are a recurring issue both in research and in the public sphere because of a perceived shortage of STEM professionals in general and women in particular (Anger et al., 2011). Currently there is a major funding initiative by the Federal Ministry of Education and Research in Germany to recruit more young people, especially women, to STEM-area subjects (cf. <https://www.komm-mach-mint.de>).

In the following section, research on educational pathways and transitions in the field of science education is shown not to be new, but limited in its definition of the object of investigation, its scope and methodology.

In the following Chapter we will first clarify the concepts of educational choices and (physics) identity that are central to the present study and draw consequences for the methodological approach. On this basis, we will specify the research interest and then present the study design, data collection procedure and the procedure for data analysis. In the results section, we present four case studies in which young women negotiate their identity in relation to physics at the end of high school. From the case analyses and their comparison, dimensions of identity work in the context of educational pathway decisions can be derived, which are finally discussed in terms of their implications for research and intervention.

## 4.1 Research Approaches to Decisions on Educational Pathways

Research on educational choices in the German-speaking countries so far has predominantly followed the quantitative paradigm, in which decisions are examined in large cohorts and a few psychologically valid measurable constructs are collected in order to make predictions. Decisions are usually examined retrospectively rather than while the process of decision-taking is still going on. These ‘mechanistic approaches’, to put it more pointedly, tend to see decisions as rational and predictable (Rabe & Krey, 2018). Although these approaches provide interesting and relevant descriptive results, there are also blind spots. Typically, transition phases are not examined in their temporal extension, because decisions are often only examined retrospectively. This means that the procedural nature of decision-making is not taken into account. In addition, the specific group of scientifically interested girls is not examined. Research in Germany has methodologically been one-sided and in particular there has to date been little research done in the field of science education that takes the perspective of identity as its focus.

Against this background it is relevant to supplement current findings relating to decisions about educational pathways at the transition from high school to further education. Our primary interest is on decisions and negotiations with regard to physics as a future field of study and profession. The study at hand therefore aims to undertake an in-depth analysis of educational choices of young women at the

transition from high school to further education, to gain deeper insights into the complexity of educational choices.

We argue that a methodological shift based on the construction of identity would help to better understand the procedural and negotiated character of decisions on educational pathways in the field of STEM. Quantitative research should therefore be supplemented by further methodological approaches. Quantitative studies with a basis in psychology are able to describe the overall situation of STEM choices by identifying distinctive factors and their correlations that influence the educational choices of young women on a larger scale. However, they fail to map the process-oriented and complex nature of educational choices at the level of the individual. As long as these characteristics of educational choices are not considered or are portrayed only to a limited extent, a deeper understanding of young women's decision-making processes with regard to physics is not possible. One way to overcome these shortcomings is through research that follows an identity approach that is now widely established in the field of science education.

In the following, two theoretical starting points – educational choices and the construction of identity – will be further explained.

## 4.2 Educational Choices: Theoretical Foundation

We assume that educational choices – leading for example to enrolment in a study programme but also to dropping out – occur in a complex negotiation process that does not end once a decision becomes manifest. Choices are therefore to be seen as long-term processes, starting in early childhood and transforming into career choices in adulthood. They are not isolated events that can be assigned to a fixed point in time (Holmegaard et al., 2014). On the one hand educational choices follow an internal logic and on the other they result from a complex set of interactions with other people and the environment. As a result, from an external perspective this decision process often does not appear to follow a linear, rational logic but might include continuous phases as well as abrupt and seemingly unpredictable moments. Finally, from our perspective educational choices are part of or are embedded in the so-called identity work of a person: “They are what they choose” (Loeken, 2015, p. 291). Numerous examples in the relevant literature show how decisions on educational pathways can be linked to identity negotiations (Archer et al., 2010; Carlone & Johnson, 2007; Carlone et al., 2014; Cleaves, 2005; Hsu et al., 2009; Stokking, 2000). In our case educational choices are therefore a matter of matching one's own identity or facets of this identity with perceptions of physics or of people related to physics.

Physics has a cultural image as being male, difficult, heteronomous and rigid, while people who pursue educational or career paths relating to physics are seen as particularly intelligent, gifted, but also less social and more “nerdy” (Allegrini, 2015; Archer et al., 2010; Carlone, 2004; DeWitt et al., 2013; Kessels et al., 2006; Lyons & Quinn, 2010; Osborne et al., 2003; Whitehead, 1996). In view of these

ideas, there often seems to be an incompatibility between self-image and the image of physics. As Andersen et al. (2014) point out, “many young people hold rather stereotypical images of scientists, making it hard for them to see themselves as future scientists” (p. 439). Such stereotypical images or prototypes, which are seen as typical representatives of a certain group of people – such as physicists or students interested in physics – are particularly relevant in so-called self-to-prototype matching, in which the self-image is compared with the prototype in terms of similarities and differences (Hannover & Kessels, 2004; Lykkegaard & Ulriksen, 2016).

The transition from high school to further education that we focus on in our study is a central biographical phase of course-setting for educational choices as well as for identity (re)construction. Not only will issues of interest in physics be negotiated, but ideas about future life in general (family, children, partnership, work-life balance, income, security, etc.) will be of interest. The individual positions him or herself in relation to these issues and balances the tension between individual agency on the one hand and the influence of social structures (requirements, norms, ethics) on the other in a unique manner.

Factors that influence educational choices are other people like parents, teachers and peers who serve as “significant others” (Sjaastad, 2012). Institutional factors like school types (Bennett et al., 2013) or the curriculum (Stokking, 2000) with particular options and access conditions (Lyons & Quinn, 2010) can also restrict or promote educational choices in specific ways.

### 4.3 Conception of (Physics) Identity and Methodological Issues

Identity is repeatedly characterised as a “messy construct”. In a first approximation, identity can be seen as the subjective feeling of stability, coherence and individuality and the notion of being distinct from others as an individual (Lee, 2012; Morf & Koole, 2014). In other words, identity is the way we think about ourselves, which involves the need to perceive oneself as a unified and consistent person. At the same time we see identity not as a characteristic inherent in the individual and coherent in itself, but as the result of constructions that are shaped by contexts (Archer & DeWitt, 2015; Archer et al., 2010; Regan & DeWitt, 2015; Smith & Sparkes, 2008). We thus follow a theoretical approach that is informed by both sociology and psychology. Due to our research interest in educational decisions *on physics*, we focus our attention especially on the processual production and negotiation of *physics* identity. We define physics identity as derived from external factors and from self-perception as well as manifested in the (linguistic) behaviour of people with regard to physics-related contents, topics and activities.

So-called “identity work” – the negotiation of one or more identities – takes place in an interplay of individual agency and the influence of social structures (Carlone, 2012). Identity has a preliminary character because it results from

ongoing construction processes through introspection, self-reflection, social comparisons and social interactions (Archer & DeWitt, 2015; Sjaastad, 2012) and identity work can therefore be considered a lifelong task.

Identity should be established in the tension between individuality and group membership (Smith & Sparkes, 2008) and to be balanced between stability versus change or variability (Shanahan, 2009).

Put simply, identity work is based on a reciprocal relationship between the individual and society. As identity is constructed and reconstructed in social practices we assume that plural identities arise within each individual (cf. Gee, 2000, p. 99) which are undergoing constant change (Shanahan, 2009, p. 58). Each identity reflects different life contexts of the individual with different properties – for example, someone can have a gender identity as well as a physics identity that are independent of each other in certain areas, but also overlap in other contexts and become hybrid: “one of the characteristics of science identity is that it is relational to other multiple identities, for example, gender identity, religious identity, and ethnic identity” (Avraamidou, 2020, p. 328).

As mentioned above, in the context of educational choices we are specifically interested in physics identity that we conceive to be a specific facet or component of one's identity. In this sense physics identity has the same basic characteristics as identity in general, but focuses on those aspects of identity that are negotiated in relation to physics – or what the person associates with physics. In line with this definition, physics identity reflects what kind of person we think we are in relation to physics, how we see ourselves in relation to physics and to people working in the field of physics (self-perception), and how we are seen by others in relation to physics (external perception). Following Carlone and Johnson's (2007, p. 1190) definition of science identity, (Hazari et al., 2010 have adapted and extended this definition), we see physics identity at the interface between performance, competence and recognition. To us, however, an issue still worth discussing theoretically is whether only a positive self-image in relation to physics should be understood as a physics identity or whether a demarcation and distanced attitude towards physics also reflects a specific – negative – form of physics identity. The difference we try to hint at is between ‘identifying with something’ and ‘identifying who I am in relation to’ Gender identity is central both for the individual and for society, and is constantly recreated in socially and culturally shaped performative practices (Allegrini, 2015; Archer et al., 2013). At the same time the perception of physics or typical physics identities in terms of prototypes or stereotypical images often conflicts with common and/or desired gender identities (Bøe et al., 2011), and this can have a lasting impact on educational decisions.

There is ample research evidence for the relevance of gender identities in the negotiation of physics identities. However, other aspects of identity, such as those resulting from the educational background of the family or from peer group membership, can also be significant. Therefore, in the context of our study focusing on physics identity and gender identity, we need to continue to be sensitive to those other facets of identity that might interact with physics identity.

## 4.4 Specification of the Research Interest

Based on the research background and the theoretical considerations above, we can formulate our research question:

How do young women negotiate their identity with regard to physics (“physics identity”) at the transition from high school to further education?

The following questions explicate aspects of the main question and serve to structure the planning and evaluation of the study:

1. How do the young women present themselves as individuals, and which self-images do they display, including their ideas about their future?
2. How do they position themselves towards their idea of physics and to “physics people”?
3. In what ways does gender and their own gender identity play a role in relation to physics?
4. Who are significant others and what roles do they play?
5. What other aspects are visible as relevant to identity negotiations in the context of educational choices?

As mentioned above, the construct of physics identity is an appropriate theoretical approach to gaining a deeper understanding of educational choices (in contrast to studies using more quantitative approaches), because it allows us to take seriously the complexity of the decision-making processes behind these choices and enables us to understand educational choices from the perspective of the individual.

## 4.5 Methodological Considerations

People make sense of their lives by telling stories or by telling *the* story of their life.

Accordingly we assume that identity work amongst other settings takes place and becomes accessible in (autobiographical) narratives (cf. Gee, 2010, p. 161), so that a specific manifestation of identity – the narrative identity – can be reconstructed from these narratives.

In autobiographical narration, talking about ourselves and events from our lives, we interpret our experiences, feelings and thoughts from the perspective of our present identity. In narratives we represent and produce situationally relevant aspects of our own identity (Lucius-Hoene & Deppermann, 2002). We reflect on the past, ascribe meaning to it and make sense of ourselves and others (Kane, 2012). In addition, the narrator positions and compares him or herself to and with other people, such as a particular physicist.

As a consequence, in our empirical study we have collected interview data that allows us to reconstruct the narrative identities of young women at the transition from high school to further education.

### 4.5.1 *Investigation Setting and Method*

Organisationally the study is affiliated to three academies of the project 'helpING!' (cf. <https://www.helping.academy>) promoted by the German Federal Ministry of Education and Research as part of a broader funding programme aiming to attract more women to STEM subjects. Three so-called 'orientation academies' have been set up that address young women at the end of their high school time or before their entry into higher education. The academies are geared towards providing orientation about possible career paths into science and technology and promoting these. In the best case the academies (viewed from the perspective of the funders) can even convince some girls that it is worth considering these professions for themselves.

The academies took place in different places in Germany over the span of 3 years, each academy lasting for about 1 week and all of them having a strong focus on social aspects in the pursuit of science. The young women have to actively apply for participation (while no application has been rejected so far), so they usually bring a certain interest in the natural sciences with them already. Besides, all participating girls are heading for the German *Abitur*, the qualification for university entrance. Thus, the participants represent a specific selection of adolescents and there is a chance that some of them are considering studying physics or related subjects. There are no costs of participation in the academies, so that the influence of anyone's socio-economic background might at least be mitigated.

Despite the fact that the academies might influence the educational choices of the participating girls, our intention with the present study is not to measure the impact of the academies; it is explicitly not an intervention study. The academies above all offer a good opportunity to pursue our research interests.

The longitudinal interview study presented here follows a qualitative approach supplemented by questionnaires and group discussions which are more related to the academies. These data are not included in the evaluation of the interviews but will be published after completion of the project. Only demographic information and data relating to interest in science from the questionnaires (conducted at similar times to the interviews) are considered.

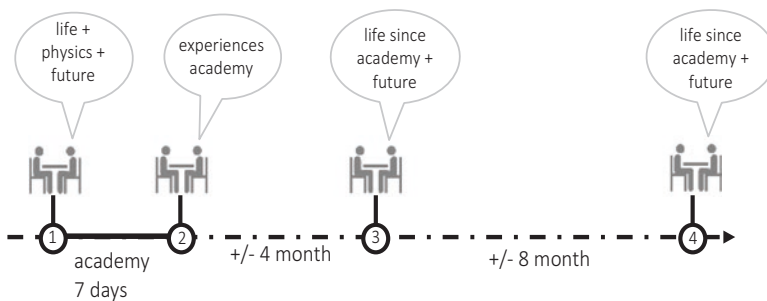
The qualitative interview study focuses on single cases drawn from a longitudinal design. With four to five participants per academy, narrative interviews are conducted at four points in time. A first in-depth interview takes place at the beginning of the academy. Three more interviews are conducted at the end of the academy, 4 months and 1 year after the academy respectively. Participation in the study is at all times voluntary. We refer here to the first ( $n = 4$ ) and fourth interviews ( $n = 3$ ) of the first academy, which took place in spring 2018, with one participant dropping out after the second interview.

The selection of interviewees is based on willingness to participate. No further theoretical sampling strategies or selection criteria (Przyborski & Wohlrab-Sahr, 2014) were applied beyond the precondition of participation in the academy. The

organisational framework of the academy and data protection considerations did not allow for a more targeted selection.

In several steps, an interview guideline was developed based on an established procedure (Helfferich, 2011; Kruse, 2015), refined with colleagues from a physics education department, revised and piloted with students. All interviews follow the scheme of starting as openly as possible and then passing into a guided interview ensuring that the topics of interest are adequately addressed. The first interview begins with open-ended prompts about the interviewee's biography, interests and people who are important to her. Subsequently, further prompts are given on the topic of physics: how was physics a topic in one's own biography, which people were important in this, how is one's own relationship to physics seen, what role did physics lessons play in this? Another interview section deals with the image of physics and physicists. Finally, questions are asked about future perspectives and especially about professional ideas. The aim throughout is to draw the interviewee into a mode of storytelling and to allow them to set their own parameters of relevance (Lucius-Hoene & Deppermann, 2002).

The second interview focuses on experiences during the academy. The girls' experiences in school and private life since the academy are at the centre of the third interview and it also serves to maintain contact with them throughout the year. The fourth interview provides both a review of the past year and an outlook for the future and focuses on the young women's ideas and reflections on their plans and wishes for the future. At the time of this last interview the young women are about to finish high school or a voluntary service and enter a phase of biographical changes. We have to assume, and we can also see from the first round of surveying, that the process of decision-making is not complete within this time and with the first choice made. In this paper we limit the presentation of the interpretation to the first and last interview due to the scope (also of the analysis), but this allows us to look at the individual cases over a long and biographically relevant period of time (Fig. 4.1).



**Fig. 4.1** Timeline and main topics of the interviews



## 4.6 Analysis Procedure

The interviews were transcribed and then analysed according to the work of Lucius-Hoene and Deppermann (2002), an approach that seeks to reconstruct narrative identity through sequential text interpretation. The approach is closely related to discourse analysis as described by Gee (2010, 2011), for example.

In analysing both the content of what is said and the specific ways in which it is said, the guiding questions are: What is presented? How or in which way is it represented? Why is it represented in this way here and now? The researchers also analysed how the narrator positions herself in relation to (relevant) others and which values and norms she refers to. Self-positioning and perceived external positioning by others are considered. The constellation of the narrating self (at the time of the interview) towards the 'narrated self' (at the time of the story told) has to be taken into account, because the interviewees naturally talk about themselves in the past from the perspective of the present. Consequently, the interpretation should take into account whether the interviewees are returning to the perspective of the past self or whether they are talking about the past retrospectively from today's perspective. In line with our research interest, we pay particular attention to how the girls talk about themselves and their lives, how they present themselves, how they relate to physics and physics teaching, how they relate to other people involved in physics, ideas about physics and gender, and what ideas about their professional future are addressed. Special features on the linguistic level are considered in the interpretation. These include the register in which the language is spoken (for example, language indicating membership of a peer group), the specific choice of words (technical terms like "theoretical versus experimental physics" indicating knowledge about the structure of physics institutes in Germany; metaphors "to hang in", exclamatory words "uh"), the use of past or present tense or formulations in the first person ("I" as opposed to an impersonal "one" or "you"). The language used gives clues to the contextualisation, to the background knowledge, implicit valuations and positioning of the narrator and also to the narrator's self-image. Since narratives are influenced by the context in which they are constructed (Kane, 2012, p. 30), the interpretation should be attentive to the interview situation (especially as the interviewer is part of the mutual construction of identity). Therefore, the interviewer's statements and the interviewees' reactions to these are also included in the interpretation.

The interviews were first interpreted sequentially, partly supported by the analysis software MAXQDA (<https://www.maxqda.com>): sequence by sequence, analysing what is said in terms of content and how it is formulated. Subsequently, the sections relevant to the research question are clustered thematically. The following focal points of analysis can be derived from the research question and the resulting interview guide: autobiographical self-representation, approach to physics and to physics lessons, perspectives on "physics people", significant others, views on women and physics, ideas about their (professional) future. Finally, the interviews

are compared with each other in order to work out similarities and contrasts and to identify the specifics of the cases.

## 4.7 Results: Four Single Cases

In the following the results of analysis are presented, substantiated by short excerpts from the interviews (for an overview see Table 4.1). The original language of the interviews is German, implying that the translation of linguistic details is also the result of an interpretation. The main focus in this chapter is on the content level of the interviews, and any fine-tuned linguistic analysis is only hinted at (see Table 4.2).

**Table 4.1** Overview of cases for interpretation

Pseudonym, age (interview 1), interview code <sup>a</sup>	Status (interview 1)	Career aspiration (interview 1)	Career aspiration (interview 4)
Sophie, 16 years, S-1	Pupil (one more year of high school)	Something related to physics	Drop out after the second interview
Julia, 18 years, J-1/J-4	Finished high school, heading for a voluntary service	Maybe research in the field of mathematics, chemistry or computer science	Applied mathematics (logistics and information management or technoinformatics)
Karolin, 17 years, K-1/K-4	Pupil (one more year of high school)	Something theoretical (e.g., in quantum chemistry)	Mathematics with physics as minor subject
Emma, 16 years, E-1/E-4	Pupil (one more year of high school)	Something related to chemistry	Computer science in a dual study programme

<sup>a</sup>The interview code consisted of the first letter of the first name and the time of the survey

**Table 4.2** Transcription rules (Nohl, 2009)

Rule example	Description
(3) or (.)	Number of seconds a pause lasts or a short pause
no:	Emphasised
mayb-	Termination of a word
no:::	Elongation, the frequency of: corresponds to the length of the elongation.
have=we	Dragging, spoken words merging into each other
(but)	Uncertainty in transcription
( )	Incomprehensible utterance, depending on length
((smiles))	Paraphrased events
@no@	Spoken laughingly
@(.)@	Short laugh
//mmh//	Audible signal of the interviewer
°no°	Very soft spoken

In order to ensure the validity of the interpretations, consistency was sought throughout the interview. In addition, interview extracts were interpreted in 'interpretation workshops' in order to be able to compare and weigh up different readings of the data. Experts from the field of science education and from pedagogy were involved in these workshops in various groupings. Particularly relevant interview excerpts were jointly interpreted sequentially and different readings of the sequences were compared and discussed.

In addition to the selection of participants, who we assume have a comparatively strong interest in STEM, the interview context can also influence the fact that certain topics are discussed to a greater or lesser extent in the interviews. Due to the extracurricular context and the academies' focus on career orientation of women in the STEM field, topics such as future planning, career choice, gender and STEM appear to be a natural topic of conversation for the interviewees. In comparison, topics such as school lessons or physics as a specific science had to be more strongly triggered by the interviewer for some participants.

The interviews were conducted by the second author of this paper, the first on-site at the academy, the second via a video conferencing system. The age difference between the interviewees was small, they were already on first name terms before and after the interviews, and did not use the German formal *Sie* form of address. This contributed to a personal and confidential interview atmosphere at eye level. Of course, the interviewees were assured of confidentiality and anonymisation of the interview data, and they had the option to end their participation in the study at any time. During the interviews, the statements were not evaluated, but attention signals were given to encourage as free a narrative as possible.

In the following, four cases will be presented and analysed along the levels of attention mentioned above: autobiographical self-representation, approach to physics and to physics lessons, perspectives on "physics people", views on women and physics, ideas about their (professional) future. Not all points are equally important in every case, but other relevant aspects – which we did not look at from the beginning – might become apparent.

Occasionally we will highlight differences and similarities between the cases. In the summary we finally relate our observations/results with findings from the wider research literature and ask what can be confirmed across the educational and social systems and where there may be particularities.

#### 4.7.1 *The Case Sophie*

In the interview with Sophie, hesitant, short answers alternate with phases in which she talks about her own experiences spontaneously and extensively. Many of her statements end with the phrase "No idea" (32 references in S-1), by which she classifies her statements as less reliable.

The keyword 'social' is central to Sophie, but in two different ways that are in contrast to each other. She repeatedly presents herself as 'weak on the social side'

and sometimes finds it difficult to deal with other people. She also sees this quality in physicists and perceives it as a similarity between herself and them. On the other hand, it is extremely important for her to pursue activities and a profession that allow her to help other people (for example, by passing on her knowledge in the context of development aid). That is why the academy's focus on the social aspects of STEM subjects was the reason for her participation.

With regard to her interest in physics, Sophie portrays herself as a 'late bloomer'. As already indicated above, in her identity work concerning physics she refers to similarities and differences to other physics people. In the first interview, Sophie first compares herself with schoolmates who were interested in physics earlier than her, to conclude that she is not a typical physics person, because she has not always been enthusiastic about the subject but "Somehow came late to physics" as she puts it repeatedly (e.g., S-1, 308f). Physics for her seems to be a topic for which typically a firm decision is made early on, whether one is interested in it or not.

However, her assessment changes when she thinks of another significant person to her, a physicist she only met by chance and who left a deep impression on her. In the course of the interview, she compares herself directly with this physicist and finds similarities in interests and communication behaviour. As a result, she states that she – Sophie – and physics fit together quite well. So here, in telling 'her story with physics', Sophie negotiates who she actually is and how she has seen herself in the past.

This can be found in other sections of the interview as well. In view of her own trilingualism, it seemed obvious to her earlier that her preoccupation with language was something she was born with. At the same time, this is an idea that seemed incompatible with seeing herself as someone with an affinity and capacity for science. Sophie's relationship, her positioning with respect to the natural sciences, thus seems to be closely linked to her self-image, which in turn undergoes biographical changes and adaptations – as does her image of physics. In addition, Sophie's interest in physics and her experience of competence are inseparably linked.

Sophie initially denies any influence of her gender on her access to physics, but after some seconds of reflection she changes her mind: "[...] That it could be that I came so late to physics because few girls think about doing something with natural sciences and uh you get it from your friends so I'm taking languages now and no idea //yes// that was also back then I think one of the reasons why I took Spanish and not umm [here she names a specific science course]" (S-1, 615–622).

Just as Sophie's interest in physics arose late, there have been changes in her career aspirations. When asked if she already knows what she wants to become, Sophie answers, "No I have a lot of @directions@ but nothing fixed uh (.) I think right now the tendency is really to physics //mhm// er since the fifth or so it was architecture all the time //yes// and then it shocked me a bit that it wasn't anymore. I don't know" (S-1, 550–552). The provisional, open character of the processes on which educational decisions are based becomes evident here – Sophie herself is amazed ("shocked") that her original clear desire to study architecture has changed to an interest in studying physics. A change she describes with "oddly enough" and "totally strange".

For Sophie, physics is synonymous with research and therefore positively linked to change and transformation. To her, physics is the opposite of boring and monotonous, especially since she associates physics with very different occupational fields (which she does not elaborate on) and fields of application. In her perception, other people regard physics as very difficult and almost unattainable, and her use of language indicates that she shares this view to a certain extent: "You have to hang in, it's far away, but not that far away" (S-1, 486). The difficulty of physics is in particular attractive for her as she mentions several times that she likes challenges and needs them in order to keep up with something: "Pretty much the hardest subject I have at school and I find that exciting" (S-1, 103). Her memories of physics lessons are largely positive, mainly because she almost always had teachers (male) who made understanding possible. She particularly likes it when the lessons do not stick to the standard curriculum which, in her view, is far from reality. Sophie seems to distinguish between physics in class and physics as it is "Really done" (S-1, 202) – the latter arousing her interest. Similarly, she distinguishes between the skills that a physics teacher needs ("The pedagogical", S-1, 375) and the skills that a physicist needs.

### 4.7.2 *The Case Julia*

Julia finished high school recently, has already participated in several science contests and was due to take up a voluntary service at the time of the first interview. In the first Interview Julia appears insecure when she talks about herself, she stumbles and interrupts her story repeatedly. But at the same time, she clearly speaks from a first-person perspective.

When asked about her special traits, she mentions her excellent memory and her mathematical abilities, which seems very self-assured at first glance: "So I think that my (.) memory could be quite good for me, because it feels like I actually remember everything. //aha// but also my (.) mathematical abilities a bit @(.)@" (J-1, 54–59). At the same time Julia marks her self-description as uncertain by using the subjunctive and formulations such as "It feels like" or "A bit". Similar to Sophie she weakens her statements. This could reflect the social expectation not to present oneself too self-confidently as a woman. Unlike Karolin (see below), however, she does not try to legitimise her statement by drawing on the perspectives of other people.

Though Julia says "I just love the natural sciences" (J-1, 414) she does not talk about physics until she's asked about it. Although this indicates that physics is not very relevant for her, she had decided to take physics as an additional subject at school. She characterises her interest in physics as intrinsic and high in comparison to fellow students who attended the same classes. Her classmates did not understand she was doing physics voluntarily: "And most of them just couldn't understand why I chose physics again (.) although I can't use it for my Abitur anyway" (J-1, 349–351).

Julia says that her gender does not play a role in her relationship to physics. While she sees advantages for women looking for a job in physics because of the promotion of women, she also mentions that women are paid less. However: “As a woman you should still stand by physics just as much as you do as a man” (J-1, 401–402). Julia seems to mix the expressions “to stand one’s ground” and “to stand by someone”, which allows two interpretations: she sees women in the responsibility to assert their position in the domain of physics and/or she feels that women have an obligation towards physics to devote themselves to physics despite any difficulties. Accordingly, it would be the responsibility of women to position themselves in relation to physics and to adapt if necessary and not vice versa.

When she is asked whether she and physics fit together, she answers positively, but at the same time in a distant and impersonal way. “I think it could fit together, (.) but then I think it all depends on what kind of field of physics. If=s is rather based on mathematics I believe rather (.) more” (J-1, 189–191). Here, as at several other points in the interview, she emphasises her particular interest in mathematics. She does not see herself as a typical physicist and compares herself with a stereotypical image whose stereotypical character she is also aware of: “I find it (.) Nothing against physicists but that they are always shown so well-behaved? //mmh//A.nd (.) so clever and mostly with glasses °or so° and I don’t think that @I could convey it like this@” (J-1, 216–219). Although she herself laughs at this statement, it becomes clear that she assumes that the stereotype should be at least partially fulfilled in order to be a physics person.

For Julia, physics is clearly linked to physics lessons, and above all to experiments. This fits in with the fact that physics is primarily an experimental subject for her, while theoretical physics – which would fit her mathematical inclinations – is unfamiliar to her: “So: (.) physics in general (.) is also very much bound (.) to (.) experiments which (.) then (.) (.) explain something resulting from it (.)” (J-1, 264–265).

Julia also raises the issue of the quality of explanations in the classroom: “Even though the teachers may sometimes (.) explain (.) strangely and assume that the students understand this, (.) otherwise I always liked physics lessons” (J-1, 237–240).

Julia’s reaction to the question of how she imagines her own future is noticeable: “So: it would be nice if you could (.) find a man @(. )@ and then a reliable (.) job or a reliable employment (.) and then at the same time if you can also do your hobbies. //mhm//and then everything fits together” (J-1, 368–372). It is noteworthy that she is not speaking in the first person at this point, although she was asked about her personal future. This could possibly indicate that her answer is guided by social norms or expectations, or that Julia has only a vague idea of her future. However, we will also see more clear statements about wanting to be close to family as guiding factors in the educational choice later in the analysis.

The first thing she mentions about her future is to find a partner, secondly, that it is a job that promises security, and thirdly, the opportunity to pursue her hobbies. Julia seems to be deliberately seeking stable structures in her life and a balance between profession and private life is very important to her (“Then everything fits

together”, see above). The importance of a work-life balance only came to the fore in Julia's last year of high school. The first interview with her already indicates that stable contacts with other people and her hobby, swimming, would probably play an important role in her decisions.

This interpretation is supported by the fourth interview 1 year later: “Yes, so I would like to continue of course in the future swimming//mhm//to find admission to a study programme (.) and then, I like (.) also to find new people, who make my studies easier (.) yes, at the same time I would also like to keep good contact with my family and with my friends, even though (.) my friends then partly will probably also move away (.)” (J-4, 120–126). Again, the first thing Julia mentions for her near future is from the private sphere – her swimming hobby that she would like to continue.

At other parts of this interview one can see that she is preparing to choose between two study programmes, both related to applied mathematics. Julia is struggling between deciding for her favourite study programme which would mean moving away from home, or to continue living at her parents' place with the swimming pool for her hobby in the back yard and with more continuity in friendships, but only with her second-choice study programme. The choice of study location is repeatedly an important topic for her in the interviews; she hopes to get to know new people in her university town, but at the same time she wants to stay close enough to her family. Her final decision is in favour of the study programme with the compromise of going home every weekend.

### 4.7.3 *The Case Karolin*

Karolin still has 1 year of high school left, has taken part like Julia in scientific competitions and already has good contacts with doctoral students of physics at a research institute. She presents herself as a self-confident individualist and rebel in general and as a high achiever and insider with regard to physics.

Karolin quickly enters a narrative flow, in which she often emphasises the extremes and which at some points indicates that she is not recounting episodes for the first time. What is striking, however, is that she repeatedly talks about other people's points of view regarding her. What others think about her is a recurring theme and seems to be particularly important and relevant for Karolin to justify statements about herself.

In both interviews Karolin repeatedly highlights her own remarkable achievements and her individuality for which she also desires recognition from others. This gives the impression that she wants to appear extraordinary to others, but at the same time wants to be seen as relaxed and laid-back. Her reaction to the same prompt that Julia received at the beginning of the interview – what is special about you – is quite different: “What else do many people say about °me°? That I (.) have very opposite sides (.) That on the one hand I can be very quiet and very thoughtful, but then again totally excited. //yes// that they find it extreme how many sides I have,

or that they did not think that I have so many interests, or that I partly do things out of the blue, something totally unexpected, uhm (.)” (K-1, 54–60). Karolin describes herself as a person of contrasts, who is quiet and thoughtful and then again excited. She even emphasises the extremes with “Very” and “Totally”. And even more, her behaviour is unpredictable for others, she “Does things out of the blue”, “Totally unexpected”. Karolin presents herself as the opposite of boring. Another central characteristic she mentions a few times in this first interview is her interest in theoretical issues, and again to the extreme: purely theoretical things: “Uhm (3) I am very interested in philosophy and purely theoretical things that would be possible or pure theories only //aha// I am a very theoretical person, practice isn’t so mine” (K-1, 49–52).

The natural sciences are central to Karolin’s life and seem to be more important than other interests. But similar to Sophie, she also stresses that she is interested in many other topics and that she differs from other “physics people” in this respect.

Karolin describes her circle of friends as important for her attitude towards physics and stresses that most of her friends are male and interested in physics: “Which is why I am influenced by this and why people often talk about physical topics” (K-1, 249–250). Other important people in the field of physics for Karolin are the doctoral students of physics who give her an insight into studying and researching in the natural sciences, her physics teacher and finally Stephen Hawking, whom she sees as a role model. The physicists at the research institute are a point of reference for Karolin when she deals with stereotypical ideas of physicists in the interview: “One has for example a certain picture of a physicist //yes// and then the picture was partly fulfilled ((smiles)) and partly not at all and that I found very interesting, because=s just proves again that quasi not only your way of being is decisive, whether you can do physics or not” (K-1, 269–273). As evidence for this statement, she then describes a woman and a man who are both physicists, but at the same time represent typical gender ideas: “The doctoral student [...] she likes such long nails ((smiles)) and she would also like to have children and something like that, //°aha!°// so she is a bit girlie ((smiles)), which I think is really sweet (.) and the other doctoral student for example only walks around in flip-flops or barefoot, no matter where he is, //yes// which I also find very interesting” (K-1, 276–282). How Karolin imagines a typical physicist can only be deduced indirectly from what she says here about physicists who are not stereotypical in her eyes. Regarding the stereotyped picture, she refers to physicists as being uninterested in fashion and not caring about their appearance, instead walking around in flip-flops. It is crucial that Karolin negates or deconstructs the stereotypical ideas based on her own experiences.

Karolin does not want to “Subordinate to her gender” (K-1, 642–644), indicating that she does not want to fulfil the typical social expectations of women’s behaviour or is willing to disregard the persistent idea that women and physics do not go together. On the contrary she sees a fit between physics and herself, because physics is something “To bite into” (K-1, 295), using the metaphor of a dog that bites into a leg and will not let go (the English phrase “to get wound up in” is a translation of the content, but uses a different linguistic metaphor). In Karolin’s eyes, physics is a



subject to be fully engaged with, which suits her self-image as someone who likes and lives the extremes (in the sense of 'all or nothing').

Karolin's opinion about physics lessons is very negative though, and she describes them as uninteresting and incomprehensible. Although she opted out of physics at school, in her free time she is occupied with physics and thus shows a certain resilience towards school experiences. Thus, she distinguishes between the subject of physics she learned at school and the extracurricular physics she has experienced.

At this first interview she mentions that she is undecided between studying physics or chemistry, and it becomes obvious that she already has extensive insights into the subjects and courses of study, even though she is a year away from graduation.

One year later, and in the fourth interview, Karolin still emphasises her preference for theory and this became the striking argument in her choice of mathematics as study programme: "Where I was really fascinated by the chemistry was the theoretical chemistry and this is also quickly just a lot of mathematics //yes// a:nd (.) I'm extremely interested in this topic, but I take just as application physics and not chemistry [she refers here to a minor subject], because that would be too practical for me again" (K-4, 217–222). Now it is not physics and chemistry in the first place, but mathematics with physics "Just as an application" that she wants to study. We assume here that her identity as a theoretical person, as she puts it before, is reflected in her choice of mathematics as a field of study. In contrast to Julia, for Karolin to change residence and to move to a new town is an attractive option when choosing a place of study.

#### 4.7.4 *The Case Emma*

Emma is in the 11th grade at the time of the first interview, so she will graduate from high school in 1 year. In her spare time, she plays water polo as a competitive athlete. She only hesitantly begins to talk about herself and seems rather restrained.

Emma gives the impression that she likes to go her own 'trial and error' way instead of the given one (E-1, 67f). This is in contrast to Karolin, who plans more strongly and attaches importance to conscious influence on her own actions (cf. K-1, 246f). Emma describes herself as an uncomplicated person who gets along with different people (in contrast to Sophie who does not see herself as socially at ease) and as someone who people come to who need an "Open ear" (E-1, 47–48). In this way Emma stresses a social ability that is stereotypically attributed to women (Briton & Hall, 1995) and which is typically rated positively by others. She mentions another characteristic only after being asked explicitly: she likes to experiment (E-1, 67ff). Somewhat unexpectedly in the context of the interview and in view of her current wish to study something related to science, by 'experimenting' she refers to the example of cooking which is again often perceived as a 'feminine' occupation (Holm et al., 2015).

For Emma, physics is primarily present as a teaching subject (e.g., E-1, 135–163) and not as a scientific discipline (as for Karolin) or as phenomena that can be

experienced. Physics is one of her two advanced courses in high school (in Germany, students at most high schools have to choose two courses at advanced level), although she likes physics only “In connection with chemistry” (E-1, 83). She also refers to physics teachers as physicists, which implies that she does not distinguish between physics within and outside of class. In connection with an internship in a crime lab it becomes clear that she likes activities related to the natural sciences and she prefers it if there are social applications to the natural sciences (she uses the word “Helping” twice in this context (E-1, 100–103)). Emma perceives that other people react with incomprehension when someone like her voluntarily chooses physics as a subject and that for these other people physics is the greater challenge compared, for example, with chemistry (E-1, 324).

When it comes to describing physics, Emma’s answer is characterised by uncertainty markers (E-1, 264ff), which are in contrast with her other answers. For Emma physics is a mixture of philosophy and maths, and she describes physics as requiring advanced theoretical thinking and only partly as a practical activity. She does not see that physics and herself fit together, “Because //mhm// it becomes very theoretical at some point and I want to do something more practical and (.) so I didn’t find anything now, umm (.) where you can do so much practical, respectively the study becomes very theoretical (.) towards the end and that’s (.) not my thing” (E-1, 183–188). This conclusion contrasts with the viewpoint of Karolin, who justifies her fit with physics precisely by attesting that physics is theoretical – so both girls perceive physics as a theoretical matter, but their conclusions are opposite in terms of feelings of rejection versus attraction.

In contrast to Emma’s description of physics as theoretical is her associating of physics lessons mainly or only with experiments (that do not work) (E-1, 139ff + 155ff). Emma describes the natural sciences as interdependent, but then suggests a hierarchy of sciences with physics at the top, followed by chemistry and finally biology (E-1, 298ff). In a similar way, Karolin also places biology at the bottom of the hierarchy (cf. K-1, 435f).

Even more than Karolin and Julia, Emma emphasises how important physics teachers are for students to enjoy the subject and gain access to it. She previously had a “Wacky teacher” (E-1, 216) in whose class she did not understand physics, whereas it was only with a new teacher that she became interested in physics.

In Emma’s ideas for the future, the goal is to find an attractive study programme and she does not think about a specific subsequent profession (E-1, 392). This study programme should in some way be related to the discipline of chemistry, and she currently favours physical chemistry (E-1, 392). Water polo will remain important in Emma’s life. Time for the family, however, will depend on the job: “That, for example, one could still fit in the family” (E-1, 415f). Like Julia, Emma is also concerned with the balance between work and family, but gives higher priority to work, to which family members somehow will have to subordinate themselves.

Emma realises that women are more likely to face pressures to justify themselves and to be looked at askance compared to men when they choose a profession related to physics, and she is aware that incomes are different (E-1, 428ff). She hopes that this will change, “That it will become normal” (that is, in her view it is not yet

socially recognised as normal that women do physics). But Emma also says that this is no reason for her to reject physics.

At the time of the fourth interview, Emma had graduated from high school and had enjoyed the support of her family during the final months. With her close family she also enjoyed talking about her future (E-4, 187f). Emma does not discuss her place of study in the interview. It is possible that this is not in question for her, but has already been fixed. At least it does not seem to be a relevant criterion for her choice of study programme that needs to be discussed (unlike in the case of Julia) (E-4, 264f) but she is hoping to leave her parental home "In order to become a little bit independent" (cf. E-4, 102f). For Emma the study format is more important. She will begin a so-called 'dual study programme' (parallel to her university studies, she will be working in a company in her future field of work) in computer science (E-4, 19f) and is already preparing for this by teaching herself programming (E-4, 9f), which she "Really enjoys" (E-4, 79).

Emma would have decided to study chemistry instead of computer science only if necessary (E-4, 177f), and she justifies this by mentioning the geographical flexibility that one would have to bring along as a researcher in the field of chemistry (cf. E-2, 183; E-3, 44f). It should be added here that in the second interview Emma said that she had found a research activity "Now quite interesting", and in the third interview she said that she intended to go into research if there were no requirement for geographical flexibility. In the first interview she had not indicated this wish.

## **4.8 Perspectives of Identity Work in the Context of Educational Path Decisions: Summary and Comparison of the Individual Cases**

In the following, the results from the four cases will be summarised, compared and related to the research literature. However, each of the cases analysed is unique and the individual findings should only be generalised with caution. The following thematic bundling of the results according to the research question is an analytical one, which is not laid out in this way in the interviews themselves. Rather, the aspects are closely interwoven.

### ***4.8.1 How Do the Young Women Present Themselves as Individuals, and Which Self-Images Do They Display, Including Their Ideas About Their Future?***

In their autobiographical narratives, the four young women reveal diverse negotiations of identity. Their different personalities can be seen in the way they tell their stories and how they present themselves. All four though have a fundamentally

positive approach to physics. However, this approach differs greatly in detail and is reflected in the fact that physics has almost no relevance (Emma) to great importance (Sophie) for their professional future.

#### 4.8.2 *How Do They Position Themselves Towards Their Idea of Physics and to “Physics People”?*

**Physics as a Whole and “Physics People”** Only Karolin already has a deeper insight into the everyday life of a physics institute and its structure and she perceives a diversity there. The other interviewees partly have an undifferentiated picture of physics and physics-related professions as well as of the natural sciences in general. This can be seen, for example, in the fact that physics is equated with theoretical work (Emma), while areas of application of physics are not discussed. It is noteworthy that the assessment of physics as theoretical leads to the avoidance of physics in one case and is evaluated as a positive attractor in the other. This fits with earlier results that a “lack of knowledge about science-related work has been the broad finding of a number of studies” (Tytler, 2014, p. 93).

All four girls in our survey refer to stereotyped culturally influenced images of physics and physicists (Kessels et al., 2006), to which they (critically) relate in the interview. It becomes apparent that the overarching discourses (“Discourses with a big D” in line with Gee, 2010, p. 34) on gender and physics play a role for all of the girls, albeit in different ways and that these discourses still seem to be viewed in a rather clichéd way. It seems that even today to relate oneself to these discourses and to position themselves in relation to stereotypes is unavoidable for young women who are thinking about a career in the natural sciences (see below). Nevertheless, it is evident from the interviews that, similarly to what Lykkegaard and Ulriksen (2016) observed, the comparison with prototypes reaches its limits when the young women encounter real people – significant others (see below) – and individual sympathies or distancing occur. Stereotypical images of people working in physics thus remain a pertinent, but by no means dominant, aspect in identity negotiations.

**School Physics** That the girls make a distinction between school physics and physics in general can only be gathered from one of the interviews (Karolin). This result contrasts with other studies that have observed differences in attitudes to school science and science in general (Osborne et al., 2003), which presupposes that these are perceived as different areas. In our cases *physics lessons* seem very important for the idea of what physics is, but tend not to be well thought of. It is not recognizable that the young women’s physics lessons promote interest in physics or that they have a noticeable orienting effect, which is a rather unfortunate diagnosis for physics lessons in Germany.

Other studies have highlighted the *role of the teacher* and the “quality of teaching as a major determinant of student engagement with and success in school subjects” (Tytler, 2014, p. 93). In telling about their physics lessons, three of the girls (all except Sophie) refer to the quality of teacher explanations which are perceived rather negatively. The girls have positive memories of doing experiments (even if they present themselves as tending to be more interested in the theoretical side), which is in line with “students often nominating these activities as positive experiences in science” (Tytler, 2014, p. 93).

In two cases (Sophie and Julia) we can see how the *institutional framework* of high school restricts access to physics. In the German *Gymnasium*, courses on two different levels (basic and advanced) are chosen after the tenth grade, which are binding for the following 2 or 3 years. In most cases only two natural sciences can be chosen. Two interviews show that these conditions prevented the choice to study (or return to) physics in school.

### ***4.8.3 In What Ways Do Gender and Their Own Gender Identity Play a Role in Relation to Physics?***

Overall, gender is an issue in the young women's negotiations. Sophie reflects that gender may have played a role in her approach to physics. Although Julia denies that it has any significance for her, it is clear from her comments that women have to “confess”. Karolin (as well as Emma) mentions that there are certain stereotypical ideas about women and physics, but that she does not want to subordinate herself to them. Emma also sees lower income opportunities for women and hopes that these will be equalised in future.

### ***4.8.4 Who Are Significant Others and What Role Do They Play?***

The influence of significant others on positioning towards physics can be seen in most of the cases. In Julia's case these are a factor in her decision-making, while for Karolin other people are rather a source of information, though she claims that she would not base her decision on their opinions. Sophie's case shows the peculiarity that a random acquaintance – a physicist – became a significant person with whom Sophie compares herself and in whom she finds confirmation for her own personality.

#### ***4.8.5 What Other Aspects Are Visible as Relevant to the Identity Negotiations in the Context of Educational Choices?***

The place of study is included in the decision for a course of study. A move to another city seems rather unsettling for Julia, while it is attractive to Karolin, who associates a move with further development of her own personality in the sense of greater independence. In Julia's case the place of study even influences the choice of the study programme, while in Karolin's case the decision for a study programme comes first and is supplemented by the additional wish to find a university with a reputation in the field of mathematics.

Considerations on reconciliation of work and family have extremely different effects on the interviewed girls. While for Julia the balance of her future private and professional life is very important, Karolin focuses more on her professional career and for Emma the family has to somehow fit into her working life and has to be subordinate to work.

Additionally, the societal usefulness and relevance of contents or the respective subject seems to be important for almost all girls, most clearly visible with Emma and Sophie.

The process-oriented and preliminary nature of educational decisions are evident in all four cases – for instance, during the survey period Karolin changed from chemistry and physics to “pure mathematics”. We observed the complexity of potential influences on the decisions in which coincidences in terms of unpredictable encounters with people who influence decision-making also play a role. This finding underpins the unpredictability of educational choices at the level of individuals as opposed to supporting a mechanistic notion of decision-making. In all this, educational choices appear to be closely interwoven with the identity work of young women. For example, when they relate to significant others, reflect on where they study or on the role of family and work in their lives, or position themselves in relation to physics, they are also negotiating how they see themselves as people now and in the future.

## **4.9 Discussion**

We initially argued that a qualitative approach that draws on the construct of identity allows access to the process-oriented and complex nature of educational choices at the level of the individual. Indeed, our data reveal a large heterogeneity within our cases, which at first glance could have been regarded as homogeneous with regard to access to physics.

Quantitative data from a questionnaire survey, conducted during the academies, indicate that all four interviewees can be classified as “interested in physics” (interest in various subject areas was rated using a four-point Likert scale). The diversity

of their attitudes to physics and to the natural sciences in general is not captured (cf. Avraamidou, 2021, p. 9) and consequently all four young women appear as likely candidates to study physics.

In the interviews, our participants were encouraged to speak about experiences and episodes from their own lives that were linked to the natural sciences and especially physics. This allowed them to start from their own personal perspective and to draw on their own ideas about what they found relevant. This specific kind of data and using identity as a lens in analysis allowed us to observe differentiated considerations within this supposedly homogeneous group of physics-interested women with regard to career choices. As we have seen, their choices have led them (so far) to other courses of study, but not physics.

The focus on identity enables a reconstruction of individually distinct superimpositions of influences on choices of study and career that are negotiated and balanced very differently by each person. This relates well to the intersectionality approach to identity, proposed by Avraamidou (2020), and underlines the need for "recognition of the myriad dynamic factors that shape decisions over time in multiple contexts" (Tytler, 2014, p. 94). Empirical survey methods intended for larger cohorts are likely to reach their limits there, because they are incapable of grasping this complexity. With the help of the interviews, however, a more in-depth analysis of the negotiation processes was possible.

The process character (Holmegaard et al., 2012) of the educational path decisions and its link to identity work also became clear. Continuities and stable identity negotiations (for example Karolin's consistent interest in theoretical approaches to the subject) can be observed as well as incidental influences (Sophie's chance acquaintance with a physicist). It is also remarkable that justifications for path decisions are not always consistently formulated at the time, so that their retrospective justifications can appear contradictory and suggest that decisions are being reinterpreted (as we discovered in Emma's interview). In this sense we see identity negotiations in the context of path decisions that are consistent yet can be contradictory over time, as has been reported before (Holmegaard et al., 2012).

To summarise, we agree that a focus on identity "provides a basis for understanding students' long-term personal connection to physics and is a more meaningful measure than a general assessment of students' attitudes" (Hazari et al., 2010, p. 979). To avoid misunderstandings, we should stress that we do not think that quantitative studies should be replaced by studies of this provenance, but rather that the approaches are complementary.

In addition, there are some implications on the methodological level. Our findings indicate that a differentiated examination of identities specific for subjects or domains is worthwhile, because the girls position themselves specifically in relation to particular subjects and do not simply view the various natural sciences in the same way. The study provides evidence that it makes sense to specifically examine the physics identity of young people and not only a general science identity. It is not easy, however, to decide at which points a separation of physics identity and science identity is possible or meaningful.

We also faced the methodological difficulty of identifying negotiation processes relating to physics, because a basic idea of narrative interviews is their openness to the relevance systems of the interviewees. To a certain extent, this contradicts the specific research interest as physics is not necessarily relevant to the young women. This point is closely linked to the question we raised above, whether physics identity always means a positive relationship to physics or whether the demarcation of a person from physics also says something about their ‘physics identity’. At the same time the negotiation of study choices in physics or other subjects is strongly overlaid by or embedded in subject-unspecific topics. For this reason, it is methodologically difficult to focus on physics-specific considerations on the one hand, but on the other hand not to overestimate their influence in relation to subject-unspecific influences. The challenge is to focus on physics identity in the interviews without over-emphasising the importance it has for the interviewees. Similarly, another difficulty is that the interviews themselves can trigger reflections among the girls (Svašek & Domecka, 2012), which in turn influence identity work and educational decisions.

From our findings, we conclude that, given the complexity of the negotiation processes, the expectations of (short) interventions aiming at recruiting more young women for science careers should not be too high. This also applies to the career orientation academies organised in the project. As the identity negotiation process starts early on and does not follow simple and always rational pathways, the probability of influencing decisions sustainably with a single intervention is low, particularly because this study shows that the social discourse on gender and physics in Germany might still refer to stereotypes to a certain extent (Kessels et al., 2006). As we saw in the data, such stereotyped images do not leave our interviewees unscathed, but require positioning towards this discourse.

Physics education at school – at least theoretically – allows for reaching all children and adolescents regardless of their parents’ home situation, social setting or cultural background. It should hence be examined more closely whether and how the physics identity of teachers is related to the identity work of students. This leads to limitations of this study with regard to further overarching discourses that are important in the German education system and elsewhere. We have not investigated how social and cultural backgrounds of the girls are incorporated into the negotiation of their physics identity and educational choices, although this is of particular importance in a society to which people have migrated, as in Germany. This points to the relevance of intersectionality. As Avraamidou (2020) argues, “researchers ought to turn their attention to gain a more comprehensive and explicit understanding of the nexus and complexity of how intersecting identities form social positioning and how this intertwines with forming a science identity” (p. 331). Likewise, the possible influence of discourses in media and social networks on positioning in relation to physics has not been taken into account, although these probably grow in importance compared to school influences (cf. Höttecke & Allchin, 2020, highlighting the gatekeeper function of social media). Future research projects should consider these aspects.

Compared to short-term and isolated interventions, in light of our results we consider physics lessons at school in particular to be responsible for improving



access to physics. Although any invitation to STEM outside of school is of course welcome, it should remain an important goal to improve physics teaching in such a way that it promotes interest and provides orientation about physics professions. In our interviews physics is often seen as a rather theoretical subject and the distinction between experimental and theoretical physics common in German study programmes is not evident to the young women. A conclusion could be that in Germany it should already be highlighted in school that there is not 'the *one* physics' and that there are many fields in the spectrum, from (industrial) applications and basic research to more theoretical or more experimental orientations as well. This includes highlighting possible links between physics and social or ethical issues, which was relevant for some of the girls. The conditions for reconciling work and family life are also, as the interviews show, still significant for young women and should be addressed further. These issues could lower the barriers discouraging young women from choosing a physics-related course or profession and thus help to reduce the shortage of female STEM professionals in Germany, an issue which has been a key driver of our research.

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