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How upper secondary students figure chemistry

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The formation of chemistry identities among students is closely linked to the norms and practices prevalent in their chemistry learning environments. However, these norms may not be equally accessible or aligned with formal assessment criteria, leading to disparities for students in cultivating a positive chemistry identity. This study investigates how students conceptualise chemistry and the opportunities it affords for identity formation. Drawing upon the theoretical frameworks of figured worlds and science identity, data were collected from 45 upper secondary school students across three Danish schools through classroom observations and focus groups. The findings reveal that students perceive the laboratory and classroom settings as distinct in purpose, nature, and relevance, with varying degrees of celebration for enacted performance in each. While work in and related to the laboratory is highly valued by both students and teachers, individual enacted performance in the classroom is often equated with proficiency in chemistry. However, implicit norms for example governing the division of labour in laboratories indicate an inequitable distribution of tasks and underscore the need for a more equitable approach to identity formation in chemistry education.

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Introduction

Within chemistry education, increasing awareness on understanding students' consideration of whether or not to choose chemistry in secondary and tertiary education, is prompted by a concern of decreased student uptake across countries (Broman and Simon, 2015; Shwartz *et al.*, 2021; Archer *et al.*, 2022). For example, a study by Broman and Simon shows how upper secondary school students seem to hold both interests and enjoyment in chemistry, but that these experiences are not necessarily translated into aspirations towards chemistry (Broman and Simon, 2015). Also, a study by Schwartz and colleagues explored the determining factors of pursuing a chemistry trajectory, by surveying and interviewing chemistry teachers and professionals. Their results showed that upper secondary school was a decisive point for chemistry choices, and positive experiences with upper secondary chemistry teaching were driving forces of later choosing a chemistry career (Shwartz *et al.*, 2021). More broadly, upper secondary school chemistry courses are crucial platforms for young people to develop positive experiences, not only to form positive attitudes towards chemistry with the effect of choosing post-secondary chemistry but also with the broader scope of supporting more young people's chemistry literacy and agency (Rüschenpöhler and Markic, 2020). A shared concern expressed across several studies within chemistry education is that upper secondary school students are not shown how chemistry is relevant for their lives outside of school or how chemistry plays a role in contemporary societal discussions such as climate and sustainability more broadly (Holbrook, 2005; Hofstein and Kesner, 2006; Childs *et al.*, 2015; Eilks and Hofstein, 2015).

Recent studies within chemistry education suggest students' chemistry identities as a promising construct for understanding how young people form affiliations to chemistry in teaching and learning settings (Broman and Simon, 2015; Hosbein and Barbera, 2020b; Corrales, 2021; Guo *et al.*, 2022). For example, Hosbein and Barbera draw on the work of Hazari *et al.* on physics identities (Hazari *et al.*, 2010), which again are rooted in a science identity construct in science education research (Carlone and Johnson, 2007), and they propose a measure of chemistry identity as constructed from a combination of mindset, situational interest, mastery experiences and vicarious experiences, and verbal persuasion (Hosbein and Barbera, 2020b). In another study, Hosbein and Barbera argue that the Science/Chemistry Identity Framework can also be a useful qualitative tool to offer a more complex understanding of chemistry identities and that future qualitative studies hold the potential to widen the understanding of the conceptualisation of chemistry identities (Hosbein and Barbera, 2020a).

While there are few studies within the area of chemistry identity, we find a small group of qualitative studies in particular that meet the above call. A cross-cutting interest within these studies is that they contribute to the complex understanding of how students' chemistry identities intersect with socially constructed categories such as gender, social background, and race

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and thus challenge the main narrative of 'chemistry as a neutral learning environment' in which all have equal opportunities to construct affiliations to the discipline (Mujtaba *et al.*, 2020; Rüschenpöhler and Markic, 2020; Corrales, 2021; Archer *et al.*, 2022). For example, Cousins and Mills, in an Australian context, show using interview data that, while girls' achievements are at level as boys, chemistry is still perceived as a masculine subject by girls. The consequence of this finding is that girls in chemistry classrooms are constructed as outsiders in chemistry (Cousins and Mills, 2015). Another example is the 'Chemistry for All' report where female English secondary school students associate chemistry with hard work/'natural ability' while receiving less encouragement, which makes their chemistry identity more difficult to build than their male peers (Mujtaba *et al.*, 2020). The same report shows students' self-confidence in chemistry to be positively associated with being male, having advantaged socioeconomic circumstances, and having high *science capital* – that is students' knowledge, attitudes, experiences, and familiarity with science (DeWitt *et al.*, 2016).

While the above studies are primarily mixed methods and/or based on interviews and focus on individual aspects of identity work, we find that there is a potential for unpacking how norms and practices of chemistry teaching and learning in upper secondary school interact with different student identities. We do so by investigating how upper secondary school classroom practices (re)produce ideas of what chemistry is, who it is for and what performing chemistry identities look like in upper secondary school. Such a direct empirical focus on the norms of chemistry is limited in chemistry education research, even though theoretical developments have been made. On the academic disciplinary level, Sjöström identifies four aspects of chemistry *discourses* (Sjöström, 2007). Here the main values of the pragmatic and practical aspects of chemistry, with its embedded connection to technology and industry, are supported, with the characterisation of chemistry not as pure science, but rather a techno-science. A different approach has been presented by Freire *et al*. who focus on *conceptual profiles* of the nature of chemical thinking related to chemical knowledge, based both on literature review and empirical data of pre-service teachers in chemistry (Freire *et al.*, 2019). Our study's starting point combines student focus groups with chemistry classroom observation. We are inspired by the colleagues above who apply identity lenses as a theoretical approach, but also how chemistry identities are entangled with the norms and practices in the classroom. In doing so we approach our investigation with a focus on the collective figuring of chemistry that students do and how this figuring shapes the way students can build chemistry identity.

Research questions

To guide our work in uncovering the collective norms of chemistry and how they affect students' possibilities of doing chemistry identity work, we propose the following research questions:

1. What norms and practices about chemistry teaching and learning are celebrated in upper secondary school classrooms?

2. How do established norms and celebrated practices support and hinder students in performing chemistry identities in general, in particular in relation to gender and science capital?

Theoretical framework

In this paper, we combine chemistry identities with the concept of figured worlds that allow for a focus on the cultural production of values, norms and celebrated practices in the classrooms (Carlone *et al.*, 2014; Günter *et al.*, 2023). The concept of figured worlds has only just been utilised in chemistry education research with chemistry as the convenient context for data collection, not as the central focus of the investigation (Nation and Kang, 2024). In the following section, we argue that the concept offers a promising potential to the research field. Other approaches have been used to investigate the implicit norms of chemistry, including the sociological, philosophical, cultural, and nature of chemistry, like the aforementioned studies (Sjöström, 2007; Freire *et al.*, 2019). Since we don't use these approaches as our theoretical framework, we will return to discuss the knowledge potential the concept of figured worlds contributes to the existing literature in the discussion.

The figured worlds of chemistry

Figured worlds have been applied as an analytical construct across STEM educational research to explore the implicit disciplinary and cultural norms that students meet within *e.g.* Biology (Günter *et al.*, 2023), Engineering (Gonsalves *et al.*, 2019), Physics (Lock and Hazari, 2016), or general Science (Wade-Jaimes and Schwartz, 2019). Holland *et al.* propose the concept as a social and cultural construct:

(...) in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others. Each is a simplified world populated by a set of agents ...who engage in a limited range of meaningful acts or changes of state ... as moved by a specific set of forces''

– (Holland *et al.*, 1998, 52)

We are inspired by the approach by Holland *et al.* who conceptualise the figured worlds of chemistry as the social and cultural spaces where upper secondary school students come to figure out who they are and who they can become through the norms and practices they participate in chemistry. Thus we understand figured worlds as the shared narratives, values, and norms (Lock and Hazari, 2016), that are established through everyday culture, meaningful acts, roles, and artifacts (Wade-Jaimes and Schwartz, 2019).

Figured worlds and power

Figured worlds are socially shaped by the people inhabiting them:

''In them, people ''figure'' how to relate to one another over time and across different time/place/space contexts''

– (Urrieta, 2007, 109).

The positions within the spaces are formed, shaped, and negotiated ongoingly, and students may not be offered equitable opportunities to position themselves within them. Positions within these figured worlds are established through the actors in these spaces and the various power mechanisms they employ.

Firstly, power dynamics emerge through learning and performing the expectations set forth by the community members within the figured world. Students become attuned to the implicit norms and standards that govern interactions within that particular academic or social space. Secondly, recognition by influential individuals within the figured world contributes to the acquisition of power and identity formation. Acknowledged by those considered valuable within the community (*e.g.*, teachers, peers) elevates one's standing and influence. This recognition can significantly impact a student's sense of belonging, identity, and agency within the figured world (Avraamidou, 2020). Lastly, the formation of identities within the figured world as we will describe next, involves positioning oneself in relation to others, either aligning with or challenging the expectations set forth by the figured world (Richmond and Wray, 2022).

Figured worlds can be conceptualised as networks of power, resembling a complex web where individuals are positioned and position themselves in relation to others. Here categories as gender and class are played out. Understanding these power dynamics within figured worlds is essential for comprehending the nuanced interplay of social forces that shape individuals' experiences and identities.

Identities in the figured worlds of chemistry

In this paper, we strive to understand how upper secondary school students experience the figured worlds of chemistry. By 'worlds' in plural, we want to enforce a focus on the potentially varied norms and practices at stake in upper secondary school chemistry spaces. Our interest lies in the students' identities that are enabled and prevented by the ways in which the figured world of chemistry is constructed across different intersecting upper secondary school spaces and classrooms (Price and McNeill, 2013). Thus, we draw on the ideas of identities as fluently, dynamically, and continuously shaped and formed in close interaction with the cultural practices (Holmegaard *et al.*, 2014) afforded by the figured worlds they are situated within (Tonso, 2006). Instead of understanding identities as accumulative cores that layer experiences within the individual, we approach identities as a concept that allows for a focus on how the individual is shaped by and shapes the cultural context they are embedded within (Avraamidou, 2020). This sociocultural perspective empowers us to understand how the figured world of chemistry sets the scene for how students come to see themselves as chemistry students, what kind of chemistry students they believe is desirable, achievable, and possible, and also why some students might struggle to do so. But also, how significant others as their peers and teachers recognise them in their positioning attempts when doing so. Thus, we see identities as the micro-level positions that students engage in when doing chemistry, positioning attempts that can be met as sensible or even celebrated with the figured worlds of chemistry or risk being rejected as such (Davies and Harré, 1990).

By doing so, we have a particular interest on how gender and social background intertwine with students' performance of chemistry students. In this study, we conceptualise performance as student enactment of social practices, especially related to school chemistry, and not as summative outcomes. Performativity, as theorised by Butler, underscores that gender expands biological sex and thus as identities above, can be approached as socially shaped through repetitive acts and positioning patterns (Butler, 2006). This approach to gender illuminates how students enact specific gendered performances within the expectations and norms available through the figured worlds of chemistry they engage in. These performances, ranging from outspoken expressions of confidence to tacit participation, significantly shape students' experiences and opportunities to construct identities within the discipline.

Finally, we are inspired by the work of Archer and colleagues on science capital within chemistry (Archer *et al.*, 2022), which has also been proposed as chemistry capital education (Rüschenpöhler and Markic, 2020). Science capital targets how young people's identities and aspirations within science are specifically oriented on the science resources they have available in their lives. One important contribution of the construct has been to shed light on the resources that young people bring with them into the school from their families and out-of-school activities, and how that are shaping young people's ideas of the extent to which science is considered something for someone like me. Science capital is composed by four factors: Who you know in science, what you know of science in and out of school, how you think or do science, and how you think about science (DeWitt *et al.*, 2016).

While we do not attempt to make a full gender or science capital analysis, we with the two constructs strive to acknowledge the aspects of the multifaceted and potentially unequal ways students' social backgrounds intersect with the figured worlds of chemistry.

Methods

In Denmark, in 2022, 72% of pupils who finished compulsory grade 9 applied for upper secondary school, with only a negligible amount not getting accepted (Ministry of Children and Education, 2024). There exists several types of upper secondary schools with different curricular focuses, most important for this study, a higher general (STX) and a higher technical (HTX), since they offer similar science-focused programmes. The largest difference between general and technical schools is how they are culturally perceived by students, with the general being considered 'opening many possibilities' while the technical is considered 'more disciplinary focused' on science and engineering (Danmarks Evalueringsinstitut, 2023). The general schools are the largest upper secondary school form in Denmark with 42% of grade 9 pupils applying, while the technical schools only receive applications from 6%

(Ministry of Children and Education, 2024). The remaining 52% apply to other kinds of upper secondary schools like vocational schools or higher business schools. Both kinds of schools offer many of the same classes and give access to the same tertiary education. In these upper secondary schools, students spend 3 years, grades 10–12, age ~16–19 years. The national sociological background of students at the general and technical upper secondary schools is similar regarding their ethnic distribution and the share of top-scoring students (from grade 9 exams). They differ in their gender profile and parental master's degrees, with 62% and 30% women and 34% and 30% parents with master's degrees at the general and technical schools, respectively (Ministry of Children and Education, 2024).

An important facet of the Danish upper secondary school structure is that students are graded every semester based on their oral performance in the classroom and on written assignments. The final grade for every subject becomes the major part of their diploma along with some oral and written exams.

Participants

The data presented and analysed in this article is part of a larger longitudinal study of 47 youth in three Danish upper secondary schools, one general and two technical. The gender breakdown of participating students in each school are: the Town School – eight girls, nine boys; The Metropolitan School – ten girls, nine boys, one non-binary; The Rural School – three girls, seven boys. Schools were chosen by the principle of maximum variation to emphasise a variety of cases (Flyvbjerg, 2011). For the parameters of the school size, socioeconomic reference,† and the percentage of admitted women the schools combined represent an upper quantile, middle half, and lower quantile school (Ministry of Children and Education, 2024). Cross-tabulating these parameters would risk the synonymity of the schools.

The students have a variety of elective subjects, but everyone has post-compulsory subjects in Mathematics, Physics, and Chemistry, which give access to 93% of all tertiary educational programmes in the categories *Science and Environment* and *Computers, Technology and Electronics* (Ministry of Children and Education, 2022a).

The three chemistry teachers both teach their respective classes in the classroom and in the laboratory, which is the common practice in Denmark.

Data for this paper were produced during students' first year of upper secondary school and are from student focus groups and classroom observation of their chemistry classes. Data was produced with the first author as observer and interviewer by doing ethnographic fieldwork on the three schools for three weeks each, with the focus groups done by the end of the visits to ensure better rapport with the students. The other authors also participated in selected individual observations and focus groups to form a more consistent basis for analysis.

Ethics

The school agreed to be part of the project by agreement by the headmaster, who recruited classes with teachers who also agreed to partake in the project. In these classes, students and teachers were asked to take part in either or both the observations or the focus groups, by filling out a form for each. 45 students volunteered to take part in both and 2 only in the observations. This leaves around 20–30% of the students in each class not being part of the project. Situations noted in observation where these students play a central role were deleted from the field notes and they were not invited to focus groups. All participating students, teachers and school names are anonymised, and their data is kept following European GDPR rules. The study was approved by the University of Copenhagen.

Focus groups

Focus groups were chosen as a method for producing data for two reasons. First, since the investigation focuses on the norms of chemistry, interviewing the students together provides opportunities for explicit discussion and meaning ascribing, about otherwise implicit characteristics in a social setting. By facilitating focus groups, we can create the possibility for more transformative interactions among the rather homogeneous students (Kitzinger, 1994; Morgan and Hoffman, 2018; Welker and Kamberelis, 2023). It is important to highlight that this does not mean this data production is unbiased. Data from focus groups will reflect the social dynamics within the group, especially in cases like this study where participants are familiar with each other (Hollander, 2004). Statements are not considered an essential opinion of the individual who expresses them but are constrained by the social order of the group. Since the point of this study is to investigate precisely such social constructs, this is rather a merit than a flaw, even though considerations about constructs such as censuring or silencing still need to be considered both when conducting the interview and in the data analysis (Kitzinger, 1994; Wilkinson, 1998; Hollander, 2004). Furthermore, the first author had a relatively short time to build rapport with the students and focus groups with classmates offer a safer environment with a less powerful interviewer (Wilson, 1997; Wilkinson, 1998; Onwuegbuzie *et al.*, 2009). To emphasise these qualities, the focus groups were held at the schools in familiar rooms, and while the students should have otherwise attended classes, which they were given exemptions from.

The positionality of the first authors isn't as clearly affecting the focus groups as the classroom observation, described in the next section. Given his known background as an upper secondary chemistry teacher, this could however affect how positively the students characterise chemistry while his own gender could affect discussions concerning gender.

† 'Socioeconomic reference' is a specific statistical construct in Danish education. It refers to how a specific year's student population of a school is compared to the entire country's student population. Variables in this calculation are: student's gender, age, and ethnicity; parent's education, employment rate, income, and criminal record; family type; number of siblings and position in sibling cohort; social measures taken against family; school's population of students with non-Danish ethnicity, and population of students with parents with tertiary education (Ministry of Children and Education, 2023).

A total of 12 focus groups were held with two to five students, most commonly with four students. They lasted $1–1\frac{1}{2}$ hours, and audio recordings were transcribed verbatim. Grouping was done at random taking into account students' availability, with a single group of students requesting to participate together, which was allowed to ensure they were comfortable with the situation (group 11). Ten groups were mixed gender, one all female (group 4), and one all male (group 11). Since the topics of the focus groups were broader than the scope of this paper, the primary data used is about a quarter of the focus groups, namely the parts concerning chemistry.

For two topics in the primary data for this paper, activity-oriented questions were used, following Colucci's list of activities (Colucci, 2007). Students were individually asked to rate chemistry on four scales before elaborating and discussing characteristics in the group. The scales asked if chemistry: had exercises with one solution/several solutions, was theoretical/practical, concerned living entities/abstract ideas, and was individual/cooperative: these scales are inspired by previous studies in academic disciplinary culture but transposed to fit the nature of school subjects rather than academic disciplines and to be understandable as empirical categorises for 16-year-old students (Biglan, 1973; Becher and Trowler, 2001). The rating itself is not used in this analysis, but the discussion and elaboration is.

The other activity-oriented question was a label generation activity where students collectively were asked to write 'What you should do to be a good student in chemistry?' on a sticky note and then elaborate and discuss, inspired by the *ideal student* concept (Wong and Chiu, 2021). The phrase: "...student in chemistry." was chosen as opposed to framing the question with "chemistry person", which has usually been done in science identity research, (Carlone and Johnson, 2007; Hosbein and Barbera, 2020b). This choice was made because the direct translation of "chemistry person" would be an odd way of referring to a person in Danish. The alternative "chemist" is closely tied to people with master's degrees in chemistry, and we thought this association might seem too distant for the students. "Student in chemistry" contextualises the activity to the familiar setting of the school, but also implicitly limits the way of associating chemistry to the school subject. We find this limitation suitable as this study focuses on the school subject.

The interview guide for the focus groups is given in Appendix 1.

Classroom observations

Classroom observation focuses on students' disciplinary work and recognition of the students by teachers and peers (Mills and Morton, 2013). The data used in this paper is only the observations made in Chemistry, corresponding to around 8 hours for each school and consisting both of classes in the laboratory and regular classrooms. Field notes were the only data from the observations, which were produced and written out on the same day by the first author.

It is important here to recognise the first author familiarity with the context, especially seen from the teachers' point of view, means that the observations are attentive to the disciplinary aspects of the classrooms and labs. This provides an opportunity to capture moments of disciplinary importance but also means that the first author already has a very well-founded notion of (his) norms of chemistry, which could make it harder to interpret students' struggle with figuring chemistry. During these observations, the first author would not interfere in activities apart from sometimes asking students about the activities they engaged in. As the first author eventually spent more time in the classroom, students would occasionally ask him simple practical questions, knowing his background as a chemistry teacher, *e.g.* '*Is this sodium hydrogen sulfate?*' or '*Do you push [the button of an autopipette] all the way down?*'. In these situations, the first author carefully considered how to not position himself as a teacher and gave equally short and simple answers.

Data analysis

The analyses of the data mainly follow a thematic analytic approach (Braun and Clarke, 2006, 2021). After reading the field notes and transcripts, and listening to the recordings, all instances concerning or mentioning chemistry were initially clustered within frames of the figured worlds approach (Wade-Jaimes and Schwartz, 2019) in NVivo (Lumivero, 2023). Within these frames, the instances were coded inductively by the first author and discussed during peer debriefings with the other authors. The codes were then clustered into subthemes of codes and subthemes later clustered into themes describing the figured world of chemistry at each school during meetings between all authors. Subthemes hence provide a more detailed description of the themes, and are not used as codes themselves. These themes were alike across the schools so instead of describing a figured world of chemistry in each school, the themes were revised to describe a *figured world of chemistry in the lab* and a *figured world of chemistry in the regular classroom*. This procedure left only a few codes that were equally present in both figured worlds. The themes are mentally connected by students as belonging to either the figured world of labs (1A: The Lab as Essential, 1B: The Nature of Chemistry, 1C: The Practices of Chemistry) or the figured world of the classrooms (2: *Chemish* (Markic and Childs, 2016)). *Chemish* is the disciplinary language of chemistry in which students are trained to learn and conceptualise chemistry through, along with content models, most profoundly, the chemistry triplet (Johnstone, 2000; Sjöström *et al.*, 2020). The themes, their subthemes, and codes that are present equally in both figured worlds are given in Fig. 1 and Table 2.

The activity-oriented questions, about good student attributes and the rating of chemistry on the four scales, underwent prior analysis before being coded like the rest of the data. The good student attribute sticky notes were inductively coded and are shown in Table 1.

The students' ratings of chemistry on the four scales were visualised as density plots with RStudio (Posit team, 2023).

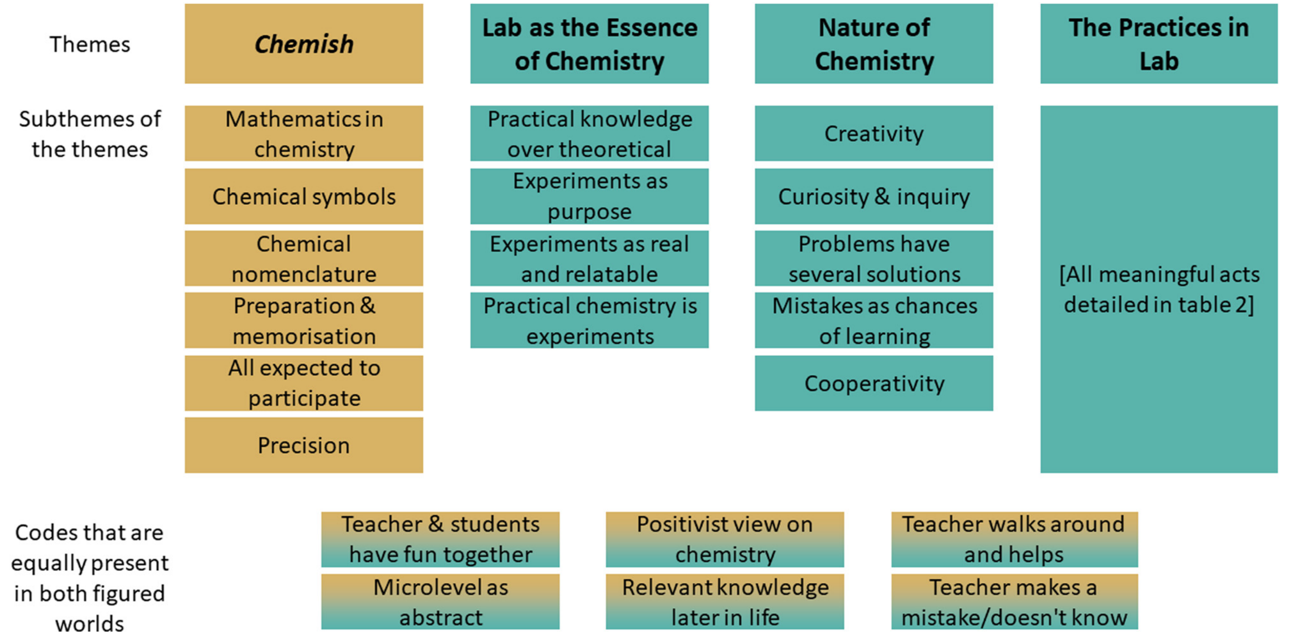

Fig. 1 Illustration of the theme construction with the figured world of the classroom brown and the figured world of the lab in teal. Themes are given in the top with bolds, then the subthemes of each theme. Codes that are equally present in both figured worlds are given in the bottom in gradiant boxes. The codes that comprise each of the subthemes are not shown here. The codes in "The Practice in the Lab" theme are given in greater detail in Table 2.

The dichotomy of the scales was used as initial codes for the coding of these parts of the focus groups where students described how, when, and why chemistry, for example, was a cooperative subject. When clustering codes in themes, these were treated like the rest of the codes from the focus groups.

The different data sources are utilised to triangulate how addressed norms are practised and celebrated by students and teachers in their cultural context. But it also provides insights when the articulated and observed figuring differs, with the most obvious example being how students value chemistry, crystalising in these two different worlds.

Table 1 Characteristics of a good chemistry student given by focus groups

Concerns figured world	Characteristics of good chemistry student
Chemistry classroom	Take notes [5] Participate [5] Know the periodic table [4] Know math [4] Know units [3] Know symbols [2] Be good at memorising [2] Be logical [2]
Chemistry lab	Curiosity [3] Patience [2] Be meticulous about chemicals [2] Be cooperative [2]
Concerns both	Listening to instructions [4] Being imaginative [3] See the big picture [2]

Note: the [number] of focus groups given a characteristic of a good chemistry student. Only shows characteristics that were mentioned in more than one group.

Translation

Since the original data in this paper was produced in Danish we follow the editorial guidelines from Taber and here outline the method of translation (Taber, 2018). Throughout this paper, we show examples from the focus groups and classroom observations. This translation is done by the first author as the paper was drafted. The transcripts of the focus groups are verbatim, so when quotes are given from these, they are translated into English but also condensed so that repetitions, students talking simultaneously, and off-topic talk are omitted, but the meaning is preserved. The audio recording was rechecked for these quotes. These translations were checked by the other authors and can be seen in Appendix 2. In combination, the authors have high proficiency in both Danish and English used in chemistry and science education research.

Results

The results are organised so that some general entry points are provided first followed by the two characterised figured worlds; 1: The Chemistry Labs and 2: The Chemistry Classrooms. Within the two figured worlds, the themes that constitute their culture, norms, and the available identities within them, are analysed by providing empirical examples from the observations or focus groups along with the data students produced during the focus groups.

An appropriate point of entry to these results is to note that chemistry is perceived very positively by all the focus groups with 30 of the 45 students describing chemistry as their favourite subject. Even though all students have chosen post-compulsory chemistry, physics, and mathematics, this still seems high. Chemistry is mandated by the national curriculum to have at least 20% of lessons with students working in the lab (virtual labs and teacher demonstrations not included), and from the observation and focus groups with students, slightly more than 20% of their time is spent in labs (Ministry of Children and Education, 2022b). Students' positive view of chemistry and the amount of lab work students are required to do are relevant contexts to keep in mind when reading this analysis. The themes of the result are presented below within the two figured worlds school chemistry manifests: the lab and the classroom. While the analysis divides the figuring of chemistry into these two worlds with different norms and cultures it is important to note that students don't see them as disconnected. The worlds are connected by content and learning, but what is emphasised is different.

Figured world 1: the chemistry labs

Discussing chemistry, all focus groups at some point made a distinction between chemistry in the lab and the classroom. For two of the schools, this also refers to two different physical rooms at the school. In this figured world themes about lab as the essence of chemistry, the nature of chemistry, and the practices of chemistry describe how students and teachers celebrate this figured world.

In the lab students typically work in groups of three to four with teachers mostly answering practical questions from students while walking around the lab and commenting/asking questions about the students' practical work. In all schools, the students are expected to find appropriate equipment themselves from cupboards in the labs, while the chemicals the students need are placed at a specific table. Lab work is always associated with some type of written data processing, usually a lab report. Before coming to the lab students are expected to have examined the procedure or to have produced their own procedure, and specific emphasis is put on hazard and precautionary statements about the chemicals, which are often reviewed in small prelab sessions.

Theme 1A: lab as the essence of chemistry

When students discuss chemistry in focus groups, the practical work done in the lab is presented as the most important and essential aspect of chemistry. Even though students agree that chemistry has both theoretical and practical aspects, they emphasise the importance of lab activities, especially when compared to physics as the following passage exemplifies.

Emma: "[comparing to physics lab]...it's not the same kind of preparation, as in chemistry with: 'Okay! Lab coat on, glasses on-'"

Alma: "'hazard and precaution phrases-'"

Emma: "'-safety'. And like, everything. That's also what's fun, in my opinion... Physics takes like 10 minutes."

Nathan: "Physics labs are simple and the theory is complex-"

Emma: "– and in chemistry is the opposite...[group all agrees]...It's also leading up to the labs...Everything we do is essentially about: 'This is all about making an experiment'. [group agrees]"

Martin: "Yes, it's something you can feel, something you can see. There is something you can test and try...There aren't aspects where you just have to imagine...Of course, you use math and make calculations, the mathematical aspects of chemistry, but the chemical aspect of chemistry is that where you test and try things, where you can see it and feel it."

– Focus group 7, Metropolitan School

Students' comparison of physics lab and chemistry lab is profound in most focus groups and as in the above passage, students emphasise the greater disciplinary importance of chemistry labs. But they also use this comparison to explain that chemistry labs are 'real' in the sense that you work with real chemicals, with real products and make real analyses, while physics lab is positioned as modelling or simulating reality. Examples that students discuss in the focus groups are that they in physics have to drop a ball in the sand to simulate a meteor crash, but that they in chemistry test the vitamin C content of vitamin pills from their local pharmacy.

The figured world of the chemistry labs is not physically confined to the lab. Homework is about reading lab procedures and writing lab reports. Classroom activities include pre-lab preparation of hypotheses, looking at hazards and precaution phrases, production of flowcharts of the procedures, and post-lab activities with data analysis and writing lab journals. Even activities that in their essence are of a theoretical nature and non-related to specific lab activities are used to emphasise disciplinary practical knowledge, as the following passage shows.

Luke finishes his presentation of the problem on the whiteboard and sits down as the class applauses and Bernie [the teacher] says: "Well done!...but! It's first useful when we can use it for something. A reaction has to occur before the fun begins..."

Bernie continues this talk which relates to how titration works. He shows a picture of a burette and a colour change.

Luke: "When do you then use ti...tration?"

Bernie: "When you have a compound that you know is there, but not how much there is. Could be salt in water."

Christina: "When you make a...titration can't you then accidentally pour too much in?"

Bernie: "Yes! That right! We can only be precise down to the size of a drop...What will happen with the concentration just where the drop hits? How do you get an even concentration in the whole beaker? ..."

– Observations, Metropolitan School

As the passage with Bernie demonstrates, disciplinary practical knowledge is celebrated outside of the lab when the students are in the classroom. This indicates another way students can engage in disciplinary identity work in the lab apart from the practical work of the lab. As we will explore later, the figured worlds of the classroom don't have such diverse ways of performing chemistry. Students also refer to the lab when explaining the external relevance of having chemistry, like 'answers real questions through practice' (Focus group 7, Metropolitan school) and 'working with and relating to everyday compounds in labs' (Focus group 10, Rural school). Similarly, another teacher, Nicole, connects a lab experiment to a real-world and relatable experience:

Nicole shows a picture from her private Facebook feed. It shows a picture of a Swedish woodland lake that a helicopter dumps chalk into. Nicole reads the Swedish text and translates some of the words.

"It looks just like the experiment you just made with chalk, just on a larger scale."

She says that many Swedish lakes are very acidic, and this is a way of neutralising them. On the Facebook feed you can see Nicole has commented: "Wonder if it worked then?"

The class asked about how the fishes in the lake respond to this, which Nicole doesn't know.

– Observations, Rural School

Even when mathematics is applied in chemistry, there are instances where the ability to refer to the practical meaning of calculations is celebrated above the internal logic of mathematics, as another passage from the Metropolitan school demonstrates:

[The class is going through post-lab calculations of the crystal water in copper sulphate pentahydrate]

...Bernie nods in a confirming manner and says: It is very unlikely that there will be no decimals ...We don't get a whole number... "Bernie takes time to look around the classroom and then asks: "So, what do we do?"

Tom: "Round off?"

Bernie: "[imitating, somewhat hasty and negligent] Yes. It's an easy math problem. 0.75, you round up. 0.25, you round down... [changes to a slow and more careful tone and pace] But what do you do in chemistry?"

It takes a few seconds before a few students raise their hands.

Christina: "...you...I think you should round down...because you are not sure where the extra comes from?"

Another girl suggests: "When you got...'comma-something', then you know...that you got more than the whole number. So, in that case, it must be better to round up?"

Bernie says: "That's exactly right." and the discussion continues about sources of errors and mistakes from the lab work.

– Observations, Metropolitan School

These examples show how the norms and practices of chemistry celebrate relatability to 'the real world'. This is linked to how students' work in this figured world of chemistry labs is also strongly correlated with the notion that chemistry is a cooperative subject. Students mostly explain this as a reflection of how much group work they do in pre-, in-, and post-labs sessions, and the sentiment that you work better together in chemistry and that cooperativity is celebrated is agreed upon in four of the focus groups. This is further supported in observations of lab work, where students always work in groups and take different roles. It poses however also some challenges as we explain further in the subsection about the practices of lab.

How the lab is perceived, in this section, shows an appreciation for the capacity of labwork to investigate what students find real and relatable problems and that doing so requires cooperativity. It also shows how the goals of chemistry are interpreted to be met by this capacity, and how theoretical and mathematical knowledge become tools to reach practical knowledge utilised in the lab, rather than goals in themselves.

Theme 1B: the nature of chemistry

Another theme associated with the figured world of chemistry labs is how students discuss the methods and purpose of chemistry, what philosophically could be thought of as the nature of chemistry. Students mostly think of chemistry as a subject where the exercise has one solution. It should be noted here that students think of physics and mathematics as subjects with absolutely only one solution, and chemistry is in that sense considered a softer subject. The discussion of the student's answers reveals this more dualistic nature. Students often start with a positivist statement about nature, highlighting that there is a real answer to exercises. They elaborate about this as the theoretical or mathematical answer, that you should be able to determine in a lab. But when the discussion translates to the lab, they point out that they often get different results between the groups, and that they sometimes use different procedures to investigate the same question. The tasks they are faced with require them to justify their methods, explain their mistakes, provide suggestions for improvement of the procedures, and compare results. In this discussion it becomes clear that what is valued in the figured world of chemistry labs is not solely the result, but mostly the procedural knowledge of using technical equipment to investigate problems and explain the merits and flaws of the procedure. The question of *how* the result is reached is more important than *what* the result is, as the following passage shows

James: "As an example, that experiment we made with pH. We didn't need to use an electrode. We could use the pH paper or the...drops... the titration, and then calculate the pH. So, I think in the experiments we make, there are many ways you can do them. And then you find that the different procedures of course give different results. And that's where you need to account for errors and uncertainties. But I think there are many ways to get the results."

– Focus group 12, Rural School

Connected to this emphasis on process rather than result is also a strongly held value that mistakes are an opportunity to learn. From observations in the lab teachers dismiss mistakes by saying that students 'can just start over', 'got plenty of material for the discussion section,' or plainly 'doesn't matter – you can learn from that'. Students' discussions about the good student contain agreement on being good at accepting mistakes, while also being creative and patient in the face of challenges in the lab:

Interviewer: "So, the 'right answers' is not about getting results?"

Lily: "No, it's about realising that you made a mistake. So, just knowing what you did wrong so that you can explain that and why your results don't completely hit the target."

Benjamin: "I actually think that knowing you made a mistake, is more demanding than getting it right...So if you are like: 'I needed to get 3%, but got 1%' then you have to ask, what went wrong. And there you learn more from having a wrong result."

Melinda and Lily: "Yes."

– Focus group 10, Rural School.

This translates clearly into the meaningful acts of the students when they make mistakes in the lab. The breaking of glassware, spilling of chemicals, extremely low-yielding results, and inconsistent results off by double digits are handled with patience and curiosity by both the students and teachers. This is not to say that students don't take pride in performing well in the lab, but mistakes are at least not an indicator of bad performance in the figured world of chemistry labs. However, to be able to cherish redoing ones work, discussing and learning from mistakes demands a learning surplus and a certain way of performing a chemistry identity in the lab.

As shown here, in the figured world of labs, there is an overwhelming emphasis on process over results in the learning of chemistry coupled with an understanding of scrutiny over experimental results. Along with the notion that chemical problems can be solved in multiple ways, this creates an understanding of the nature of chemistry which at first glance seems multifaceted and where different ways of performing and having competence can be recognised. However, as we shall see in the following these opportunities are more available to some students than others.

Theme 1C: the practices in lab

The meaningful acts concerning labs and the artifacts of lab can be divided into the pre-/post-lab sessions and the session where lab work is performed.

During lab sessions, students most commonly perform their experiments in four-person groups. These groups are sometimes organised by the teacher, but none of the teachers ever explicitly state what kind of roles or acts there could be in these groups. In the following, we give an example from the observations of the Rural school's classes with lab work (Table 2). The actions are labelled as meaningful because students perform them in direct relation to their disciplinary work in labs, but this doesn't mean that the performance is equally celebrated. Based on how much the actions require disciplinary competence, performance with tools in the lab, and disciplinary interactions with meaningful others, acts can be ranked from most meaningful to least meaningful:

(1) When a student actively shows off, they show a high degree of certainty in their own competence or performance, while actively seeking recognition from peers or the teacher.

(2) Discussion of experiments and management of experiments require disciplinary competence and a certain degree of recognition of one's own competence to take part in while handling equipment show disciplinary performance.

(3) Acts such as fetching and cleaning equipment still require some amount of disciplinary competence and performance but are less connected to experiments. Relatedly, secretarial acts (like taking notes and pictures), the announcement of results, and active spectating are more general school performances.

The large lab groups mean that there often aren't enough meaningful acts for all students to do all the time. Nonetheless, some students manage to perform many different types of acts, while other students perform few types of acts or spend much time non-participating. To illustrate this point, we now focus on a few examples of students from the same school. Since these students performed the same experiments for the same number of hours they make a better comparison:

Benjamin and Lily are examples of students who can be seen performing many acts and many different kinds of acts, especially those of high disciplinary value, including showing off and discussing and handling equipment. In the classroom, Benjamin and Lily are also high-performing students who often answer and ask questions. Interestingly they often work together, which underlines that one high-performing student does not necessarily make it impossible for other group members to perform many different acts. Considering Benjamin and

Table 2 The meaningful acts of the example students observed in the lab

Meaningful act & *example*	Benjamin	William	Lily	Phillip
Show-off to other students/teacher				
Benjamin finds what he refers to as a 'very big magnet'. He shows it to his group who are also excited by it.	5	2	1	0
Discussing experiment				
Lily and Benjamin discuss if the change of colour is visible enough	6	5	5	1
Handling lab equipment				
William and Elijah set up their electrode	6	9	7	2
Managing experiment				
Benjamin read aloud to the rest of the group what equipment they need	1	0	2	0
Fetch lab equipment or chemical				
Benjamin fetches the vinegar	3	0	0	0
Clean up				
Lily drops a pipet which breaks. The whole class keeps calm and Lily picks up the pieces of glass and disposes of them.	3	2	2	0
'Secretary'				
Benjamin measures the sodium hydroxide and tells James who notes it on his PC.	1	1	1	0
Seek out help				
William ask Benjamin how to use the autopipette	2	1	1	0
Announce result				
Philip announces the measurements	1	0	0	1
Spectate				
William performs the titration while David, Phillip, and James stand close around the burette and watch him.	1	0	0	2

Note: number of times a specific meaningful act was observed in chemistry labs at the Rural school for the four students in focus. A total of 5 hours were observed in chemistry labs over 3 different days.

Lily's performance, it is not surprising that they do many meaningful acts in the lab.

William is an example of a student who also performs well in the classroom, just like Benjamin and Lily. In the lab and in his lab groups, he is often the group member who does most of the physical actions of lab work and manages what the rest of the group does. His group members handle lab equipment less and do not show off or discuss without him. William always performs highly valued disciplinary acts, while leaving less valued acts to other group members as, he is not at all involved with fetching equipment, being secretarial, spectating, announcing results, or processing data.

Phillip is a student who talks less in the classroom but is competent when working on problems and when he is asked to present. However, he is unlike the other types of students described here, as he constantly does almost no meaningful roles apart from handling equipment and spectating.

The meaningful acts of showing off in the lab are especially interesting. Firstly, these acts highlight interest in the disciplinary activity or artefact shown off, they display and celebrate a disciplinary performance or competence, and they anticipate recognition from other significant actors. Secondly, a third of all these acts are performed by the same student, Benjamin.

Besides the example in Table 2, Benjamin engineers a way to fasten his electrode so it does not need to be manually held (they don't have standardised equipment for that), he collects trash from all groups and deposits it in a chemical waste bin in the depot, he shows another group how to use an auto pipette (after the first author showed him how it was used), and shows data to another group that had a different result. In themselves, these actions need not be show-offs, but they all become so as Benjamin announces them loudly or directly to the teacher and is recognised by students and the teacher. These acts of show-off are often related to other acts that legitimise them through the power of the teacher.

Benjamin's show-off of the auto pipette came about because he randomly found it and recognised that it must be more precise than their glass pipette. He then sought the first author out to learn how it was used and was shown. The lesson before Benjamin fastened the electrode, he asked the teacher what the liquid inside the electrode was. As the teacher couldn't explain from memory, Benjamin was taken aside and shown a book where an explanation was provided. In the book, a picture of a fastened electrode was given, which Benjamin noted. This can be seen as an act where Benjamin first seeks recognition from the teacher and then later uses his confirmed position and new competence to perform in front of his peers, to gain even more recognition.

We find the empirical examples illustrate at least three important points.

First of all, the observations show that not all students, even those who perform well in the classroom, receive training in specific lab competencies as they get distributed amongst students and that not all students seem to have equal access to performing all competences as for example Phillip, who only perform very general acts that are not well recognised in the figured world of the chemistry lab.

Secondly, we interpret Benjamin's performance as strongly associated with classical masculinity in the way that he loudly and actively navigates the lab, how he attracts attention and recognition from the teacher and peers and leaves some of the less meaningful tasks to his group members. With *masculinity,* we refer to an understanding that is based on performance, not statically gendered (Gonsalves *et al.*, 2016), while the *classical* refers to what previous research has found to be gendered behaviour in science (Cousins and Mills, 2015; Gonsalves *et al.*, 2016; Quinn *et al.*, 2020; Archer *et al.*, 2022; Günter *et al.*, 2023). However, Benjamin seems to work well together with Lily who equally performs well in chemistry but does not loudly and explicitly exhibit her competences. Also, William takes on the physically active role of performing tasks in the lab, distributing work to group members – yet without exhibiting his competencies as strongly as Benjamin. Thirdly, we notice how not only gender but also science capital seem to be intertwined with the distribution of tasks in group work. When looking at the students' backgrounds it is noteworthy that Benjamin, Lily, and William are the only students in the class who come from families with a background in STEM, an indicator of higher Science Capital. Even though there are other students who perform different meaningful act without these relations, those who perform the fewest and least meaningful are those students with limited Science Capital in their family background. This indicates how students can translate their Science Capital to support their chemistry identity.

How students figure the world of the chemistry lab shows that this space is of high disciplinary importance to the students and to the way they conceptualise chemistry. Having only had chemistry as a separate subject for three to six months, it is notable how the nature of planning for, going to, and analysing results from the lab is seen as the essential nature of chemistry, especially as students emphasise this compared to physics. These same norms can also be seen in the implicit way the teacher positions artefacts and acts from the lab as meaningful and relevant, like the use of burettes and neutralisation. This figuring makes it important to be attentive to the acts and roles students can perform as they can serve as a means to build chemistry identity.

These themes and examples illustrate how students create meaning in this figured world of lab chemistry. The lab is seen as a space of chemistry, where the subject's school knowledge can be applied and give meaning to life and surroundings. It goes beyond the physical space of the laboratory itself, with practical knowledge and applications engrossing theoretical knowledge. It shows how chemistry is regarded and performed cooperatively and creatively, with an emphasis on the learning of procedures and room for failure, instead of a confirmatory hunt for the right answer. Overall, this offers a positive and diverse figuring of chemistry, socially and creatively, with a praise of the technological practices of chemistry. However, when students perform acts in this highly celebrated space, it is not all students who have access to perform equally. The three students, all of whom have access to science capital from their backgrounds, are top performers in the lab. Because no explicit instructions are given on how to delegate labour, this leaves students to negotiate their roles, which might not be easy to figure out, even for students like Phillip, who performs well in the figured world of the classroom.

Figured world 2: the chemistry classrooms

The figured world of chemistry classrooms is much smaller in terms of how much students articulate it in focus groups even though observations show that students also spent a significant amount of time working on chemistry that doesn't explicitly concern laboratory work. In two schools, chemistry classrooms are regular classrooms referred to as the class *homeroom*. So, it is the same classroom where students have History, English and other classes. They are both organised with a whiteboard and projector at one end of the room along with a teacher's desk and then students sitting in four to five rows with free seating. In the Rural school, the lab is also used for classroom teaching. In this space, there is also a whiteboard and projector, but students sit at high tables in groups of four, which also serve as desks to perform experiments. In this figured world of chemistry classrooms, activities involve short teacher lectures, where students are expected to ask questions and answer questions, sessions of problem-solving where group collaboration is normal, and walk-throughs of these problems both done by teachers and students. Analysing the conversations around the characterisation of chemistry, this figured world primarily describes the individual and theoretical aspects of chemistry, and in students' characterisation of a good student, this figured world is much more profound than the figured world of lab as shown in Table 1.

Theme 2A: chemish

Looking at all the codes from observations and the focus groups, it is clear to us that the overarching theme in the figured world of chemistry classrooms is best described by the performance and celebration of *chemish* in the classroom (Markic and Childs, 2016). The kind of celebrated performance that *chemish* entails in this figured world, distinctly not in the figured world of chemistry labs, is exemplified by this discussion:

Jason: "I feel [the good student in] Chemistry is missing a post-it, which should be called 'detailed'...[Lilian and Debra agree]... Because Ezra [the teacher], cares a lot about details."

Lilian: "But, he did say, once, that he is a 'splash chemist'.‡ So, you don't need to be so precise when you measure things."

Jason: "Yes, when you measure things."

Lilian: "Yeah, that's right of course."

Jason: "But, it is like this. If you have to describe something, then you have to go into every detail. Otherwise, you won't get full points. And then he doesn't like it properly."

Lilian: "Uhh...yeah, that's right."

Jason: "Or if you a drawing a model, yeah, those you must be able to explain really well. Otherwise, it's not good enough."

– Focus group 1, Town School

As this group discusses, attentiveness to linguistic detail and precision matters in a very different way in this figured world. Many students describe how good student characteristics of *knowledge of the periodic table*, *knowing symbols, knowing units,* and *memorisation* are directly related to this notion of precision. The most striking consequence of the importance of having these competencies is the mention of 'the STAR rules', which the students directly mention in half of the focus groups, is explicitly stated by two teachers, and is a physical poster in one of the classrooms. 'The STAR-rules' is a content model originally created for physics in Denmark which helps remember what aspects are important when writing out the solution to a problem. It is based on an acronym which tells you to: (1) write an information box. (2) Write the formula. (3) Write the units. (4) Check the significant figures. (5) Write a one-sentence abstract. From our observations, it is clear that these rules are highly celebrated by the teachers when the teachers and students speak in the classroom, and especially when students are asked to go through problems on the whiteboard, in front of the class. Even though the teachers practice this in different ways, nothing stays written on the whiteboard if it doesn't follow the rules of *chemish*. As students make mistakes in the drawing of bonds, naming of compounds, symbols in equations, or subscripts in formulas, teachers are explicit about every mistake made, as this longer passage is an example of:

[the class have been working on problems and after a break, they return]

Bernie [dramatically excited]: "And now to the problems!"

Arthur cheers silently in a similarly dramatic way. Bernie looks at him with a smile and says: "That was nice. You are going to the whiteboard." Arthur is a bit perplexed by Bernie's spontaneity but gets his PC with notes and is at the whiteboard 30 seconds later and starts explaining the problem concerning calculating the amount of lead in kale. It doesn't go well for Arthur and every time he writes or speaks, Bernie asks him a new question. It concerns every detail in the calculation and Arthur's precision in language. Significant figures, symbols, and equations. Arthur's largest problem is that he has a hard time writing, with the correct notation, what he is saying. He says that 'we need to divide the mass of lead with the mass of kale'.

Bernie: "Don't you wanna write that? It sounded really good."

Arthur looks a bit hopeless as he slowly writes:

$$\frac{m}{m}$$

Bernie: "m divided by m is just one. So... how did we do last time we needed to distinguish?"

Arthur continues to write:

$$\frac{m(\text{lead})}{m(\text{kale})} = \frac{0.000103\ \text{g}}{214\ \text{g}} = 0.0481\%$$

Bernie asks Arthur why he uses three significant figures, which Authur correctly explains. Bernie then asks about the zeros, 'Isn't there something wrong?' Arthur can't figure this out and after trying, and failing to correct this, he says that he doesn't know.

‡ 'Splash chemist' original Danish is *sjatkemiker. Sjat* is commonly used in cooking when referring to a small but not measured quantity. So here, a chemist working in the lab, without being (or needing to be) precise.

Bernie calmly says: "That doesn't matter. One can learn from this. Powers-of-10-mistakes are the most common sloppy-mistakes. You see them quite often."

Bernie finishes the calculation with scientific notation, which Arthur didn't use, and turns to the class and announces clearly: "You should all familiarise yourself with scientific notation. We will work both with very small numbers and very large numbers."

As Arthur returns to his chair Bernie and the class applaud him [they always do when someone has been up at the whiteboard].

– Observations, Metropolitan School

This passage exemplifies several aspects of what are considered meaningful acts in the figured world of the chemistry classroom, including the attention to the precise use of *chemish*, along with students having a strong notion that mathematical ability is also somewhat important to chemistry. Many students hold the view that mathematics competence is somewhat fundamental to all science competence. Arthur's example shows the explicit and demanding performance celebrated by students and teachers in this figured world. When most of the students refer to *note-taking* and *participation* as characteristics of a good chemistry student, this is the kind of situation they refer to. Participating thus means that you are actively engaged in class, solve your problems, participate in classroom discussions, ask the teacher questions, and then approach problems as Arthur did. Note-taking is very much seen as preparing yourself for these kinds of situations and hence a strategy to prepare you to make this kind of performance. The explicit performance of these performances is dreaded by many students and sometimes a source of outright fear, as discussed in 7 of the focus groups, like this passage:

Teddy: "[Ezra, the teacher] appreciates you…So, that you…he likes that you know what we do in class… [group agree]"

Stella: "I have a good example. He wrote a bunch of formulas…and then we had to say what they were. And when someone said the right name, he became really happy. And then, when someone got it wrong, you just get the death stare…[laughs]… so, you to prepare."

Kyle: "He will still say 'yes', but like 'yeeess', in a disappointed way."

– Focus group 3, Town School

As the example shows, students understand the celebration of performance in a particular manner by labelling scientific terms rather than exploring their conceptual understanding. This allows for a narrow way of performing chemistry and hence limits the ways of building chemistry identity. This could be seen in the example with Arthur, and in the following example where no student can opt out of this performance without it being noticed:

Nicole shows the next problem on the whiteboard which shows a lot of acids and bases. Students then have to give the strength of the acid/base and write the corresponding one.

Nicole: "Everyone can just write something on the board for this exercise. Volunteer first, so you can take some of the easy ones" She finishes with a gentle smile, puts her pen down and steps back from the whiteboard to take a seat on one of the empty student chairs, looking at the board and those who come up.

The students now go up in a rather unorganised manner. William and Andrew race to the whiteboard to get there first. William gets there first, then Andrew, then James, then Benjamin, then Elijah and Phillip. Wendy checks her answers with Nicole before she goes up. Then Lily goes up.

Nicole: "I don't think everyone has been up yet. There are still a few compounds left…"

It doesn't affect those few students who haven't gone up yet, as it is obvious to all who are missing. After some long and silent seconds, Benjamin gets up to complete another one, which Nicole allows.

– Observation, Rural School

How students figure chemistry in this space stands in rather stark contrast to the figured world of chemistry labs. The way students highlight extreme meticulousness in their use of *chemish* (*e.g.*, nomenclature, symbolism, calculations) is unlike the notion that you learn from mistakes in the lab, or that chemistry is a subject inviting creativity and diverse ways of problem solving. What is celebrated here is an individual performance of specific tasks where the individual exposes own competencies in front of the class with narrow often right and wrong outcomes, as opposed to the cooperative nature of the lab. These views are simultaneously held by students, as they make sense of this contrast by reference to the different figured worlds of lab and classroom. Even though students relate the figured world of the lab as essential and concerning the nature of chemistry, they don't disregard the figured world of the classroom as superfluous. They neither seem to actively consider the discrepancy in their description of the essentialism of the lab and the main characteristics of good student behaviour to be mostly associated with the classroom.

Discussion

We will now address each of the research questions and discuss the findings related to each of them, looking across the results of the two figured worlds we have shown.

1. What norms and practices about chemistry teaching and learning are celebrated in upper secondary school classrooms?

The result of the analysis shows how students hold two distinct ways of figuring out chemistry, and how students value these worlds from the different sources of data is noteworthy. The discussion during the focus groups where students describe what chemistry is, how it is done, and why it is done mainly concerns the figured word of lab. Students, in their own words, and through the emphasis of the teachers, implicitly celebrate this way of conceptualising chemistry. However, when students discuss what makes good chemistry students, their focus is vastly shifted toward a celebration of chemistry described in the world of the classroom. This conception of the good student reproduces aspects found in other research about good students like the *successful* high school chemistry student involving memorisation of non-contextual matter, which is unsatisfying but leads to good grades based on 'traditional school performance' (Rop, 1999) or the *ideal university student* where *Diligence & Engagement, Organisation & Discipline*, and *Positive & Confident Outlook* are ranked as the most significant characterisations (Wong *et al.*, 2023).

The observations support this way of figuring chemistry in two different worlds, with two different sets of norms, cultures, and meaningful acts. Students can be seen performing differently in these two worlds along with teachers explicitly celebrating different performances in the different worlds. This creates challenges for allowing all students to be able to see themselves in chemistry and negotiate a chemistry identity.

Students' ways of figuring chemistry in the lab and in the classroom might at first hand not seem a surprise given the spatial separation the lab and the classroom often have. But it is worth stressing how the students figure the world of lab beyond the physical confines of the labs, as shown in the way they attribute aspects of classroom activities to this world and celebrate practical knowledge within and outside of the lab. This shows that performance in the figured world of the lab comes in many different ways. In this manner, students normalise the duality instead of the dichotomy between 'the lecture and the laboratory' (Talanquer, 2012). It is however obvious that students also hold a very conflicting view when they address the world of the classroom, with the attributes of uncreative focus on individually performed verification and memorisation in their learning of *chemish*.

As a consequence, there is a risk of presenting the students with an unconstructive misalignment between the learning outcome and the assessment (Seery *et al.*, 2024). Since the figured world of the lab presents so many aspects that are praised norms in the chemistry education literature there should be a focus on valuing this way of figuring chemistry. These praises include:

• The humanisation of chemistry with greater emphasis on application, contextualisation, and social chemical knowledge (Sjöström and Talanquer, 2014; Seery *et al.*, 2024).

• The opportunities for creativity, a shift from right answers to the process, and the conception of failure as a learning opportunity (Vesterinen *et al.*, 2009; Agustian *et al.*, 2024; Seery *et al.*, 2024)

• The techno-scientific nature of chemistry, with its focus and celebration of practicality and societal relevance duality (Sjöström, 2007; Vesterinen *et al.*, 2009; Chang, 2017; Freire *et al.*, 2019).

• The conceptualisation of the holistic nature of the Chemistry Triplet, along with the added dimension of intrinsic relevance (Johnstone, 2000; Talanquer, 2012; Sjöström and Talanquer, 2014; Eilks and Hofstein, 2015).

This figuring of chemistry also aligns well with the purpose of chemistry described in the Danish curriculum (Ministry of Children and Education, 2022b) and with the top three recommendations to improve chemistry by Swedish students, connection to everyday life, lab work, and student-centred work (Broman and Simon, 2015).

The fact that students focus so heavily on classroom performance attributes when they describe the good students can be related to the fact that students receive a grade in oral chemistry based on the teacher's perception of their performance in chemistry. It is however clear that grades shouldn't be based alone on performing well at the whiteboard, but reflect all the aspects of the curriculum, for instance including their performance in the lab (Ministry of Children and Education, 2022b). The performing and participation in answering teacher questions, as obvious performance-makers may overserve their purpose here and unintentionally make the ways in which students can perform their *chemish* very narrow. This relation between how teachers and students ascribe meaning to how students perform to receive their oral grade is beyond the scope of this study but should be investigated further, given the backwashing effect exams (which this grade counts as) have on teaching and students' performance.

This is not to emphasise that learning or celebration of the performance in *chemish* is unimportant as it has been proven central to both the contemporary and historical discourse of chemistry as a disciplinary-specific aspect of scientific language (Liu and Taber, 2016; Markic and Childs, 2016).

2. How do established norms and celebrated practices support and hinder students in performing chemistry identities in general, and in particular in relation to gender and science capital?

Every classroom and subject has norms that shape the culture within them, these are not neutral and give affordances to certain kinds of students and affect how students can build chemistry identities.

When students associate the performance in the figured world of labs so little as they do, this may be because of the unclear indications of what is important and what is celebrated here. The lab can be seen as a complex open learning environment when driven by self-organised group work (Agustian, 2022). The analysis shows how students with high science capital excel in this open lab environment taking on central, meaningful acts such as experiment management. Conversely, those with lower science capital often find themselves relegated to less recognised positions like secretarial duties or equipment cleaning. Such power dynamics underscore how the chemistry lab, as a celebrated space, serves as a gatekeeper shaping student identities. For instance, Philip, despite excelling in classroom chemistry, finds his competence disconnected from celebrated lab tasks, being assigned less meaningful work. Moreover, we find that the performance of meaningful acts is closely associated with classical masculinity as delegating and assigning tasks to other group members or loudly and explicitly exhibiting lab competencies to the teacher and peers. Yet, it is noteworthy that Benjamin and Lily manage to work together while still doing many different actions in collaboration. This somewhat contradicts the study of Doucette *et al.* who investigated lab work in physics. They find that in mixed gender groups, females either take on all the tasks of the group or that groups employ a Tinker-Secretary division of labour, with the female as Secretary, depriving her of opportunities to make scientific investigations and both roles to practice each other's tasks (Doucette *et al.*, 2020). Literature in chemistry education research has given many reasons for having and valuing lab education, with an overview in (Agustian, 2020, 2.1) and there are points about that in the Danish national curriculum of chemistry (Ministry of Children and Education, 2022b).

In physics education, there has been a stronger tradition to investigate, especially the gendered division of labour in the laboratory. Holmes *et al.* find that women are just as interested as men in working with lab equipment physics, while women have a stronger preference to take notes and men have a stronger preference for making analyses. Collaboration is also shown to be the preferred way of working in the lab by students, especially by women, despite the observations that they do divide work. (Holmes *et al.*, 2022). Quinn *et al.* find that students tend to perform a single kind of behaviour in physics labs with little intra-group variance in structured physics labs. When labs are loosely structured women more often do laptop work while men handle equipment, without assigning this division (Quinn *et al.*, 2020). We do think our study shows clear inequities that should be investigated more in chemistry education. Especially given the lack of studies that focus on the division of laboratory labour and the inequalities it brings to chemistry education. The findings from physics education research suggest a gendered division of the labour in labs, which is somewhat in line with our own findings (Doucette *et al.*, 2020; Quinn *et al.*, 2020; Holmes *et al.*, 2022). Our cases with Lily and Phillip, and the overall trend of students with high science capital performing diverse tasks in the lab does however indicate that an intersection lens reveals more nuances than just the gendered or science capital lens alone. If the laboratory is important, as we think it is, then all students need opportunities to train in laboratory skills.

Chemistry education literature does provide suggestions to mitigate some of the inequities we find in our study. Teachers can work with implementing specific tools that make it more obvious to students that their performance in the lab is recognised such as assessing with a variety of methods along with lab skills (Seery *et al.*, 2024) for instance like the digital badge approach with filming of students performing and explaining tasks (Towns *et al.*, 2015).

The Process Oriented Guided Inquiry Learning (POGIL Project, 2023) gives a framework to explicitly work with group roles, but is not specifically focused on the lab and studies about the group roles within this framework, have been described as under-theorised (Rodriguez *et al.*, 2020).

Regarding a more open and diverse way of learning *chemish* Mönch and Markic have developed and evaluated how teachers can increase their pedagogical scientific language knowledge to educate students in the *chemish* (Mönch and Markic, 2023). Kielferle and Markic also show how the learning of *chemish* can be successfully incorporated into laboratory work, especially in a homogeneous student population (Kieferle and Markic, 2023).

Limitations

It is important to identify some contextual points about this paper. Firstly, these students have already chosen chemistry and science beyond compulsory classes, and the figuring they do could be very different from students in compulsory classes of chemistry, as the relevance, attitude, and scope of chemistry couldn't be perceived very differently. Secondly, the way students receive a performance-based grade in Denmark, which counts towards their final exam, should influence how heavily performance is celebrated. This aspect of our findings might be very different from school systems where students for example are only graded based on written exams.

We also want to highlight that we focus on how students figure chemistry through norms. Our data provide no insight into individual identity work or teachers' thoughts, as no individually focused data is used in this study, like individual interviews.

Lastly, we want to address the 20–30% of students at the three schools who did not want to partake in the study. These students, in general, participated in classes to a lesser degree than the students in the study. Combined with our first mentioned limitation, this suggests that students in our study are not only choosers of chemistry and science but generally also engaged.

Implications

Given the novel approach of this study to investigate the norms of chemistry, we have shown how essential the laboratory is for students' conception of chemistry, yet undervalued when it comes to characterising how good students should perform. It would be interesting to explore how students figure chemistry in other contexts, both related to the level chemistry is taught at and in other countries.

The importance of the lab to the construction of diverse ways of understanding and realising chemistry for students also adds another reason to emphasise lab work as an essential part of chemistry education. Had students not had the experiences of the lab, how might they have figured chemistry? As many educational systems at secondary and post-secondary levels divide or exclude lab from classroom chemistry, this might affect many students around the world. While our study can only speculate on this matter, it invites further investigation in this area.

Our intention was not to make a feminist analysis or a thorough science capital study, but more generally to study the figured worlds of chemistry. Since this aspect of inequity of tasks in the labs, who performs them and how roles are negotiated wasn't the sole design of this study, we strongly encourage further investigation should be made into positions and tasks in the laboratory in chemistry education, as it already has been in physics education. These kinds of investigations could also look into ways of making the celebrated performance in and related to laboratory work more explicit for students.

As we find the figuring of chemistry split into two worlds, it would be worthwhile to investigate if this is a fruitful way of conceiving chemistry or whether the aspects of *chemish* celebration are better combined with the lab world, preferably with a more diverse way of performing allowing more students to build chemistry identity.

For educators, our findings highlight the importance of having explicit assessment criteria that align well with the applied and reflective competencies students need to gain in chemistry. The emphasis on the laboratory and the broad nature of chemistry that it presents, show the potential that this space has to learn the competencies and culture of chemistry. Educators should work with ways to make the practices of the lab more equitable as this study shows some of the opportunities and pitfalls that implicit and unstructured division of labour holds.

Conclusions

This study analyses the figured worlds of laboratory and classroom chemistry and how they each play a significant role in providing, enabling, recognising, supporting, or declining, neglecting, and rejecting various student identities. We do so with a close focus on the historically established disciplinary practices of school chemistry, that over many years have been the foundation for establishing norms of what is recognised as chemistry and who are recognised as chemistry students.

By providing rich qualitative analysis of focus groups with and observations of students and teachers in chemistry classrooms, this paper challenges the narrative of chemistry as a neutral learning environment in which all have equal opportunities to construct affiliations to the discipline.

While the figured world of the laboratory is celebrated by students as the essence of chemistry, they at the same time characterise good performances in chemistry as mainly happening in the figured world of the classroom. This presents a challenge because it undermines all the valuable and diverse features of the lab and sets a narrow way of performing chemistry.

Our findings vividly illustrate how positions within both chemistry labs and classrooms are shaped and negotiated by both students and teachers, often resulting in inequitable opportunities for different students to assert themselves. Established norms and celebrated practices significantly influence the figured worlds where students' construction of chemistry identities takes place. This particularly interacts with students gender and science capital. Our analysis reveals that students with high science capital excel in the lab, undertaking pivotal tasks, while those with lower capital are relegated to peripheral roles. This underscores the chemistry lab's role as a gatekeeper in shaping student identities. Moreover, the association between the performance of meaningful tasks and classical masculinity underscores the complex interplay of gender dynamics in lab engagement.

Author contributions

The first author produced, coded, and led the analysis of the data as well as produced the first draft of the paper. The second and third authors supported the analysis and writing of the paper. They also supervised and led the project GATE which this study is a part of.

Data availability

Data for this article can, as prohibited by the signup form of participating students and teachers, not be shared in its full non-anonymised form outside the project group of the authors. The data is originally in Danish and the selection of raw data shown in the article has been translated to English. Materials used in the article, besides the raw data from human participants, can be shared by contacting the corresponding author.

Conflicts of interest

There are no conflicts to declare.

Appendices

1. Focus group interview guide

The interview guide used for the focus groups is provided in English, along with the original Danish in Table 3. Only the questions concerning chemistry, which are used in this study are given, but similar questions were given about physics, mathematics, and technology. In the beginning, they were told about the themes to be discussed, their synonymity, and were specifically invited to comment on each other and ask each other questions.

2. Translation of data examples

In this appendix, the English translation of examples of data used in the article is given along with their Danish original. The Danish originals are still meaning-condensed from the verbatim transcripts of focus groups, where especially students talking over one another and giving small confirmations are cut. The data examples are given in the order they appear in the article.

Focus group 7, Metropolitan School. *Emma: "[comparing to physics lab]…it's not the same kind of preparation, as in chemistry with: 'Okay! Lab coat on, glasses on-"*

Alma: "'-hazard and precaution phrases-'"

Emma: "'-safety'. And like, everything. That's also what's fun, in my opinion… Physics takes like 10 minutes."

Nathan: "Physics labs are simple and the theory is complex-"

Emma: "– and in chemistry is the opposite…[group all agrees]…It's also leading up to the labs…Everything we do is essentially about: 'This is all about making an experiment'. [group agrees]"

[*some time later after finishing talking about physics*]

Martin: "Yes, it's something you can feel, something you can see. There is something you can test and try…There aren't aspects where you just have to imagine…Of course, you use math and make calculations, the mathematical aspects of chemistry, but the

Table 3 Translated and original interview guide for focus groups

English interview guide	Original Danish interview guide
I would like you to tell why you chose your programme of elective subjects.	**Jeg vil gerne have til at fortælle hvorfor I valgte lige netop denne studieretning som I går på nu.**
What elements were important for your choice?	Hvilke elementer var vigtige for jeres valg?
Did you expect specifics about the programme of electives you chose?	Forventede I noget bestemt af studieretningen da I valgte?
Does it live up to your expectations?	Lever det op til jeres forventninger?
[Activty with rating of subjects]	**[Aktivitet med bedømmels af fag]**
I would like to hear your thoughts about how you perceive chemistry in relation to the other subjects. You should rate chemistry on these axes. Then you show them and afterwards, we will discuss why you rate chemistry as you do.	**Jeg vil gerne hører jeres tanker om hvordan I ser kemi i forhold til andre fag. I skal placere nogle kemi på disse akser. Så vise I dem og derefter taler vi om hvorfor I har placeret kemi som I har.**
Can you elaborate on how chemistry is [category]?	Vil I uddybe hvordan kemier [kategori]?
What do you do in chemistry to make it [category]?	Hvad gør man i kemi for at det er [kategori]?
What would you say is typical for teaching in chemistry?	Hvad vil I sige er typisk for undervisningen i kemi?
Are there different kinds of teaching in the subjects?	Er der forskellige typer af undervisning i hvert fag?
What does it mean for the way you can participate?	Hvad betyder det for den måde man deltager på?
Is there any subject that is more important to be good at than other subjects?	**Er der nogle fag det er vigtigere at være bedre til end andre?**
Are any subjects more prestigious than others?	Er der nogle fag med større prestige end andre?
What is your favourite subject?	**Hvilke fag kan I bedst lide?**
What is it you like about this subject?	Hvad er det ved disse fag I godt kan lide?
[Activity with sticky notes]	**[Aktivitet med post-its]**
I would like to hear your ideas about what you should do to be a good chemistry student. We can write on notes and then elaborate.	**Jeg vil gerne høre jeres opfattelse af hvad man gør hvis man er en god elev i kemi. Vi kan skrive på post-its, og så uddybe.**
So, if a new student started in your class and you should give advice on what to do to be good at chemistry, what would you then suggest?	Så, hvis en ny elev startede her i klassen og I skulle givet råd til hvad eleven skulle gøre for at være god til kemi hvad ville I så foreslå?
What do you do particularly in chemistry?	Hvad gør man særligt i kemi?
What do you do that is different between the subjects?	Hvad gør man forskelligt i fagene?
Does it require anything in particular to do this, which makes you good?	Kræver det noget bestemt at kunne denne handling som gør en god?
Are there gender differences?	Er der en kønsforskel her?
	Når man får karakterer i fagene, er det så disse egenskaber man bliver bedømt ud fra?
When you are graded in chemistry, is it then these characteristics you are judged on?	Hvad bliver man ellers bedømt ud fra?
What else are you judged on?	Er der nogle bestemte typer af elever der bliver bedømt bedre eller dårligere?
Are there specific kinds of students that are judged harder or softer?	

Note: translated English interview guide for focus groups along with the original Danish. Bold phrases indicate questions or topics always addressed and non-bold phrases indicate help questions, which was not always needed.

chemical aspect of chemistry is that where you test and try things, where you can see it and feel it.''

Emma: jeg... at så... der er ikke den samme form for forberedelse som der er med kemi med'okay, nu skal vi have kitler på, vi skal have, øh, briller på, og vi skal stå her og vi skal-Alma: Og vi skal først undersøge HP-sætninger. Emma: og vi skal undersøge sikkerheden' og alt muligt, og alt det der, sådan, er sjovt ved det, hvis du spørger mig. Hvor fysik...Altså, det tager 10 minutter.

Alma: Ja

Nathan: Det f-altså, selve forsøget er simpelt, men teorien bagved er meget mere kompliceret-Emma: Ja, og det er også bare, sådan-Alt det vi laver, handler egentlig om'det her skal udende ud i et forsøg'. Nathan: Ja.

[samtale forsætter om fysik før den vender tilbage til kemi]

Martin: Ja, det er noget man kan føle ved, det er noget man kan se, det er noget man kan teste på, det er noget man kan prøve på. Det er ikke noget hvor du skal tænke *dig* til det. Ja, øhm, som jeg sagde, det er noget man kan føle på og se på. Og måske egentlig, når man snakker lidt mere om det matematiske i det så ja, men det tager jeg mere som, sådan, matematik i kemi. Jeg siger mere det kemiske i kemi er det med test og prøver, hvor du kan se det, du kan føle det.

Observations, Metropolitan School. *Luke finishes his presentation of the problem on the whiteboard and sits down as the class applauses and Bernie [the teacher] says: ''Well done!...but! It's first useful when we can use it for something. A reaction has to occur before the fun begins...''*

Bernie continues this talk which relates to how titration works. He shows a picture of a burette and a colour change.

Luke: ''When do you then use ti...tration?''

Bernie: ''When you have a compound that you know is there, but not how much there is. Could be salt in water.''

Christina: ''When you make a...titration can't you then accidentally pour too much in?''

Bernie: ''Yes! That right! We can only be precise down to the size of a drop...What will happen with the concentration just where the drop hits? How do you get an even concentration in the whole beaker? ...''

Luke får lov at sætte sig, klassen klapper og imens siger Bernie: ''Det er godt!...men det bliver først fornuftigt når vi kan bruge det til noget. Der skal ske en reaktion før det bliver sjovt…Jeg har en ting. Blandt den med noget andet. Så sker der noget …" Bernie forsætte fortællingen som handler om hvordan titrering foregår. Han viser et billede af en burette og et farveskift af noget væske i en Kolbe.

Luke: "Hvornår bruger man det så, ti…trering?"

Bernie: "Når man har noget stof, som man ved hvad er, men ikke ved hvor meget man har af det. Eksempelvis, salt i vand."

Christina: "Når man så laver…titreringen…kommer man så ikke til at hælde lidt for meget i?"

Bernie: "Jo! Det er rigtigt. Vi kan kun være præcise ned til en dråbe…Hvad vil der ske når man tilsætter sådan dråber, med koncentrationen lige hvor dråben lander? Hvordan får vi en ens koncentration i hele kolben?"

Observations, Rural School. *Nicole shows a picture from her private Facebook feed. It shows a picture of a Swedish woodland lake that a helicopter dumps chalk into. Nicole reads the Swedish text and translates some of the words.*

"It looks just like the experiment you just made with chalk, just on a larger scale."

She says that many Swedish lakes are very acidic, and this is a way of neutralising them. On the Facebook feed you can see Nicole has commented: "Wonder if it worked then?"

The class asked about how the fishes in the lake respond to this, which Nicole doesn't know.

Nicole viser et billede fra hendes private facebook. Det viser et billede af en svensk skovsø hvor der bliver dumpet kalk i vandet far en helikopter. Nicole læser opslaget op på svensk og oversætter ord der ikke er lige til at forstå:

"Det ligner jo forsøget I lige har lavet med kridt, bare i større skala."

Hun fortæller mange svenske søer er meget sure og dette er en måde at neutralisere det på. Man kan se Nicole har kommenteret på opslaget med: "Gad vide om det så virker?" Hun uddyber med at hun ikke ved hvordan det påvirker dyrelivet i søen.

Observations, Metropolitan School. *[The class is going through post-lab calculations of the crystal water in copper sulphate pentahydrate]*

…Bernie nods in a confirming manner and says: It is very unlikely that there will be no decimals …We don't get a whole number…"Bernie takes time to look around the classroom and then asks: "So, what do we do?"

Tom: "Round off?"

Bernie: "[imitating, somewhat hasty and negligent] Yes. It's an easy math problem. 0.75, you round up. 0.25, you round down… [changes to a slow and more careful tone and pace] But what do you do in chemistry?"

It takes a few seconds before a few students raise their hands.

Christina: "…you…I think you should round down…because you are not sure where the extra comes from?"

Another girl suggests: "When you got…'comma-something', then you know…that you got more than the whole number. So, in that case, it must be better to round up?"

Bernie says: "That's exactly right." and the discussion continues about sources of errors and mistakes from the lab work.

Bernie nikker bekræftende og siger så: "man skal dog nok passe på ikke bare at tage resultatet, for det kunne jo godt være et skævt talt…Det er meget usandsynligt det passer helt præcist…Det kan godt blive et skævt tal…Vi får ikke et helt tal. Hvad gør vi så?"

Tom: "Runder af…?"

Bernie: "Ja! Det er nemt matematisk. [immitererende] 'Har man, 75 runder man op. Har man, 25 runder man ned'…Men hvad med i kemi?"

Christina: "…man…jeg tænker man runder ned…for man er ikke sikker på hvor det ekstra kommer fra."

Pige: "Når man har… komma-noget, så ved man jo …man har noget mere end det hele tal. Så er det vel bedst at runde op."

Bernie: "Det er nemlig rigtigt."

Focus group 12, Rural School. *James: "As an example, that experiment we made with pH. We didn't need to use an electrode. We could use the pH paper or the…drops… the titration, and then calculate the pH. So, I think in the experiments we make, there are many ways you can do them. And then you find that the different procedures of course give different results. And that's where you need to account for errors and uncertainties. But I think there are many ways to get the results."*

James: Jeg har det sådan lidt, altså for eksempel, øh, det forsøg vi lavede med PH, øh, PH-værdien, det er ikke fordi vi behøvede at gøre-med en elektrode, og så kunne vi jo også bruge, så, det der PH-, øh, værdipapir. Øhm, og så tror jeg også der var hvor vi kunne titrere det og så finde pH'en ved at udregne det. Så på den måde så synes jeg at, sådan, altså også i de forsøg vi laver der er mange, sådan, hun finder mange måder at gøre forsøget på. Og sådan-og så finder man selvfølgelig frem til de der forskellige, øh, øh, resultater der. Og så er det-det er jo også, øh, på grund af nogle fejlkilder, men jeg synes egentlig der er mange, sådan, løsninger på hvordan man kan, altså, komme frem til resultater.

Focus group 10, Rural School. *Interviewer: "So, the 'right answers' is not about getting results?"*

Lily: "No, it's about realising that you made a mistake. So, just knowing what you did wrong so that you can explain that and why your results don't completely hit the target."

Benjamin: "I actually think that knowing you made a mistake, is more demanding than getting it right…So if you are like: 'I needed to get 3%, but got 1%' then you have to ask, what went wrong. And there you learn more from having a wrong result."

Melinda and Lily: "Yes."

I: Så det rigtige svar handler egentlig ikke om at få resultatet. Lily: Nej, det handler om at se-at, okay, øhm, altså, indse at man har lavet den her fejl der eller vide at, åh, det var der vi lavede en fejl. Altså, bare det der man har kontrollen over-eller, hvad kan man sige, ved hvad, altså, hvad man har gjort galt og bare forklarer det, fordi så har man ligesom forklaringen på, at man har så-et resultat der måske ikke rammer helt inden for det, som der var formålet.

Benjamin: Jeg tror faktisk det at man ved hvad man har gjort galt, det kræver næsten mere end at få det rigtigt. Øh, fordi hvis du får det rigtigt, jamen, så kan du faktisk bare smide det ind forskellige steder, tallene du har fået. Og så-så har du et svar, så du kan aflevere det. Men hvis nu du siger'okay, jeg skulle ramme 3 procent et eller andet, og der står altså kun 1 her', så er det sådan, okay, hvor er det her gået galt? Og der lærer man-der lærer man næsten mere af at have et forkert svar.

Lily: Mm.

Melinda: Ja

Focus group 1, Town School. *Jason: "I feel [the good student in] Chemistry is missing a post-it, which should be called 'detailed'…[Lilian and Debra agree]… Because Ezra [the teacher], cares a lot about details.*

Lilian: "But, he did say, once, that he is a 'splash chemist'.‡ So, you don't need to be so precise when you measure things."

Jason: "Yes, when you measure things."

Lilian: "Yeah, that's right of course."

Jason: "But, it is like this. If you have to describe something, then you have to go into every detail. Otherwise, you won't get full points. And then he doesn't like it properly."

Lilian: "Uhh…yeah, that's right."

Jason: "Or if you a drawing a model, yeah, those you must be able to explain really well. Otherwise, it's not good enough."

Jason: Jeg føler Kemi mangler en sticker, der hedder detaljeret…

Fordi Ezra går meget op i detaljer.

Lilian: Bortset fra han har sagt én gang, at han er sjatkemiker, så du behøver ikke være helt præcis, når du måler ting op.

Debra: Ha ha ha.

Jason: Ja, når man måler ting.

Lilian: Ja, … det er selvfølgelig rigtigt.

Jason: Men det er sådan noget, hvis du skal beskrive noget, så skal det gerne sådan være helt i detaljer, ellers får du ikke fuldt point, eller så kan han ikke lide det ordentligt… Eller hvis du skal skrive en model op, ja, dem skal du kunne beskrive rigtig godt, ellers så er det ikke godt nok.

Observations, Metropolitan School. *[the class have been working on problems and after a break, they return]*

Bernie [dramatically excited]: "And now to the problems!"

Arthur cheers silently in a similarly dramatic way. Bernie looks at him with a smile and says: "That was nice. You are going to the whiteboard." Arthur is a bit perplexed by Bernie's spontaneity but gets his PC with notes and is at the whiteboard 30 seconds later and starts explaining the problem concerning calculating the amount of lead in kale. It doesn't go well for Arthur and every time he writes or speaks, Bernie asks him a new question. It concerns every detail in the calculation and Arthur's precision in language. Significant figures, symbols, and equations. Arthur's largest problem is that he has a hard time writing, with the correct notation, what he is saying. He says that 'we need to divide the mass of lead with the mass of kale'.

Bernie: "Don't you wanna write that? It sounded really good."

Arthur looks a bit hopeless as he slowly writes:

$$\frac{m}{m}$$

Bernie: "m divided by m is just one. So… how did we do last time we needed to distinguish?"

Arthur continues to write:

$$\frac{m(\text{lead})}{m(\text{kale})} = \frac{0.000103\ \text{g}}{214\ \text{g}} = 0.0481\%$$

Bernie asks Arthur why he uses three significant figures, which he correctly explains. Bernie then asks about the zeros, 'Isn't there something wrong?' Arthur can't figure this out and after trying, and failing, to correct this he says that he doesn't know.

Bernie calmly says: "That doesn't matter. One can learn from this. Powers-of-10-mistakes are the most common sloppy-mistakes. You see them quite often."

Bernie finishes the calculation with scientific notation, which Arthur didn't use, and turns to the class and announces clearly: "You should all familiarise yourself with scientific notation. We will work both with very small numbers and very large numbers."

As Arthur returns to his chair Bernie and the class applaud him [they always do when someone has been up at the whiteboard].

Bernie visker tavlen og beder eleverne finde opgave 67, 68 og 69 frem som de skulle have kigget på. Det gør de og Bernie siger: "Vi går nu til opgaverne om opløsninger."

Arthur siger muntert og lavmælt: "jaaaa". Bernie smiler til ham og siger: Det var godt. Kom du til tavlen. "Arthur bliver lidt slået ud af Bernie spontanitet og skal først lige have slået op på opgaven på hans PC, men efter 30 sekunder står han ved tavlen.

Bernie stiller han så mange spørgsmål og Bernies opmærksomhed er også rettet meget skarpt mod den Arthur. Bernie spørg til en hver detalje i opskrivning, betydende cifre, symboler og formler. Arthur går i gang med opgaven og fortæller 'at vi skal lave milligram til gram. Der går 1000 milligram per gram.' Arthur fortæller så at man skal tage massen af bly og dividere med massen af kål.

Bernie: "Vil du ikke prøve at skrive det du lige har sagt. Det lød rigtig godt." Arthur ved dog ikke hvordan han skal indikere forskellen og skriver lidt håbløst:

$$\frac{m}{m}$$

Bernie: "m divideret med m giver jo 1. Hvordan viser vi forskellen?…Hvordan gjorde vi før?"

Arthur opskriver så parenteserne og skriver videre:

$$\frac{m(\text{lead})}{m(\text{kale})} = \frac{0.000103\ \text{g}}{214\ \text{g}} = 0.0481\%$$

Bernie spørg først til de betydende cifre og Arthur forklarer der er 3 og de kommer fordi de andre tal i opgaven har 3 betydende cifre. Bernie spørg så til nullerne, om ikke der er noget galt. Arthur kan ikke gennemskue dette og efter forsøg på at rette konstatere han at han ikke ved hvorfor hans tal er 1000 gange for stort.

Bernie: "Det gør ikke noget – det kan man lære af. 10-potenser-fejl er de mest typiske sjuskefejl. Man ser dem så tit."

Bernie færdiggør regnestykket og slutter med at sige: "I bør vænne jer til videnskabelig notation. Vi kommer til at arbejde både med nogle meget store tal og meget små tal."

Arthur får lov at sætte sig. Klassen og Bernie klapper og Bernie skriver formlen op.

Focus group 3, Town School. *Teddy: "[Ezra] appreciates you…So, that you…he likes that you know what we do in class…[group agree]"*

Stella: "I have a good example. He wrote a bunch of formulas…and then we had to say what they were. And when someone said the right name, he became really happy. And then, when *someone got it wrong, you just get the death stare...[laughs]... so, you to prepare.''*

Kyle: ''He will still say 'yes', but like 'yeeess', in a disappointed way.''

Teddy: Så er han... Så er han sådan meget glad for dig. Han, sådan..., han... Nå, så du kan alt det her... Han er sådan... Han er meget glad for at du ved hvad vi laver i timen.

Stella: Jeg har et godt eksempel, fx vi skulle sige de forsk..., han opstillede nogle forskellige formler og sådan noget, hvor det var vi skulle udtale hvordan det var de var. Og så når det er at folk siger det rigtigt, så bliver han rigtigt glad. Ja. Ja. Ja. Og så er der en der siger det forkert, og så får man bare døds-blik-ket, ha ha ha. Så man skal lave sine ting.

Kyle: Han siger stadig ja, men det er sådan, jaaaaa...Skuffet agtigt.

Observation, Rural School. *Nicole shows the next problem which shows a lot of acids and bases. Students then have to give the strength of the acid/base and write the corresponding one.*

Nicole: ''Everyone can just write something on the board for this exercise. Volunteer first, so you can take some of the easy ones'' She finishes with a gentle smile, puts her pen down and steps back from the whiteboard to take a seat on one of the empty student chairs, looking at the board and those who come up.

The students now go up in a rather unorganised manner. William and Andrew race to the whiteboard to get there first. William gets there first, then Andrew, then James (who brings his laptop), then Benjamin, then Elijah and Phillip. Wendy checks her answers with Nicole before she goes up. Then Lily goes up.

Nicole: ''I don't think everyone has been up yet. There are still a few compounds left...''

It doesn't affect those few students who haven't gone up yet, as it is obvious to all who are missing. After some long and silent seconds, Benjamin gets up to complete another one, which Nicole allows.

Nicole ruller næste opgave op som er navnet på en masse forbindelser i et skema hvor der så skal angives styrken af den syre/base og det korresponderede stof.

Nicole: ''Alle skriver bare op på denne opgave. Så meld jer først, så I kan tage nogle af de nemme.''

Eleverne for nu lov at gå op uden at Nicole udpeger eller indikere på anden måde hvem der skal til. William og Andrew gør konkurrence i hvem der først kan rejse sig fra bordet. William kommer først, så Andrew. Derefter James, som tager sin PC med op og støtter sig til. Så Benjamin, Elijah og Phillip. Wendy vil have tjekket sit svar inden, så Nicole går hen og bekræfter det er rigtig, hvorefter Wendy går op med PC-støtte og skriver sit svar. Derefter går Lily op.

Nicole: ''Jeg synes ikke alle har været oppe. Der er stadig opgaver tilbage.''

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