FROM STUDENT TO EXPERT IN A WEEK

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ABSTRACT

It can be challenging to effectively impart higher education content to students. We experienced such difficulty in a lecture series with invited senior scientists presenting their area of Biotech research. Instead of a vivid exchange with the expert, we observed limited and restrained student contributions. In qualitative interviews with these students we learned that they perceive their knowledge disparity as too big and the fear of being embarrassed by asking “stupid” questions obstructed their participation. This let us to radically rethink the course design resulting in our own interpretation of flipped classroom, peer learning and student empowerment. We designed an engineering course that focuses on providing master students with the best possible environment to gain theoretical knowledge in a new field within a limited time period (currently: six weeks - six topics) aiming to empower them in these topics by acquiring new knowledge on their own. Based on seed questions and tag words, students conduct background research and create a team presentation for an invited field expert, thereby getting prepared for a subsequent in-depth discussion with the expert. The current layout is the product of an iterative process over the course of five years, and several rounds of fine-tuning within each year, based on extensive student and instructor feedback. Students particularly appreciate the positive in-course atmosphere with a focus on growth-mindset, the strong experience in teamwork, being taken seriously, and making contact with field experts and frontiers of current knowledge.

1 INTRODUCTION

We designed a lecture series intended to bring students of the Biotechnology Master’s programme rapidly to an advanced level of understanding of bioanalytical methods. Our plan was to capitalise on the rich expertise found in the Berlin area as one of the leading cities for German science, so we invited experts to present their area of research to the students. Our assumption was that students would benefit

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from top-level teaching by the experts and, as a side effect, make contact with excellent research groups for potential master thesis projects.
The original course format was a classical lecture series with two 90 minutes slots per week. We taught our core expertise and allocated the remaining slots to field experts. After running this course twice, we concluded that engaging scientific experts to teach their respective topics with passion and profound domain-specific knowledge provided an excellent framework for professional teaching. However, the oral exams with the students also revealed a substantial shortcoming. The topic-specific experts had condensed the content that they normally teach to PhD students and postdocs in field-specific scientific courses over a week or two into three to six hours, which was the time allocated to them. While none of the students had any questions - a possible signal of complete understanding - we interpret this now as a sign of information overload. None of the students had conquered the knowledge that they had been provided with, as evidenced by the oral exams and further interviews with the students.
To address these shortcomings, we fundamentally reconceptualized the course by implementing a mixed method format built on flipped classroom [1] and project-based learning concepts [2]. Here we report on the process, the design and the experience of running the course in its reworked form for five years.

2 METHODOLOGY

2.1 Research questions

The low learning outcome despite the substantial framework of expertise strongly indicated the need for a new course concept. So, we went into ideation defining the following main needs:

- How can the students gain confident command of the current state of development of selected bioanalytical methods in the life sciences within the restricted time boundaries of the course?
- How can we maximise the value of leading experts in their respective technologies that volunteer teaching this course, while keeping their time commitment minimal?

We reframed the first question into the core idea of the course in a more accessible way: How would a couple of friends ideally learn the theory of a new technology within one week, or even less? How can they achieve that repeatedly for every topic without feeling lost or overworked?

2.2 Methodology of course development

With the problem explained in the introduction and the needs summarised within the research question(s) we created a course prototype based on a mix of concepts like flipped classroom and project-based learning in expert groups with a focus on activating learning methods.
For the first version of the course (prototype, Fig. 1) we reserved three subsequent days per topic with the experts being invited on day 3. This initial format was used to further learn about the participants' needs by critical observation and regular feedback sessions after each topic round, directly linking to the implementation of minor adaptations (fine tuning) for the following topic.
Based on these experiences and a vast feedback collection we iterated the course for the next year that again was the basis of the following iteration loop. With that strategy we were able to adapt the course structure to its current format (year 2021) that is further described in the results section.

2.3 Evaluation of learning success

In order to display the learning success for each course topic, we designed a questionnaire (see Fig. S3) and asked students to evaluate their confidence levels within each subject on a scale of 0 (lowest) to 10 (highest).
We started data collection on a voluntary basis in 2018 with a printed 2-page questionnaire that was expected to be filled out before the start of the course and then regularly after each course day. Sheets were collected at the end of the course and data points displayed as box-and-whisker plots, individually for each topic (fig. S1), and as a mean of all topics (Fig. 2).Students were also asked to evaluate their team-, research- and presentations skills before and after the course based on a similar scale (Fig. S2).
The same type of paper questionnaire was used in 2019 and, since 2020, has been replaced by a digital survey with identical topic and skill related questions, now only being accessible at the time of data collection.
To also get the impressions of the invited experts, we asked them to rate the students' performance in an informal feedback session after the course. Finally, we graded students with a portfolio exam (compare section 3.2).

3 RESULTS

3.1 Prototype development and theoretical background

From the initial shortcomings we learned that students need preparation time to learn basic concepts and translate these into further questions to feel comfortable to interact with and hence effectively benefit from the experts. One way of doing that would have been to give students selected materials prior to the expert lecture to be worked through at home. That way of flipping the learning from the classroom to out-of-class might have already resulted in prepared students and more time in class for further discussion of the content [1]. However, in other courses we have observed that only a certain number of students follow these recommendations, and even fewer master the content in depth. Also others have observed insufficiently prepared students, even if the pre-work was mandatory [1, 3]. To help students focus and assist whenever needed, we decided to integrate the preparation phase into the classroom.
In their review about problem- and project-based learning, the authors describe that a problem to solve might act as an incentive for students to learn and can be used as a central principle to enhance students' motivation [2]. So instead of just letting students prepare with topic related material, we expected them to create a team presentation about the method within two days that finally should be presented to the expert. Proven to enhance deeper understanding [4, 5] we implemented peer learning by splitting the course into expert teams of four to six students. Each team was then randomly assigned one predefined subtopic of the collective final presentation, meaning that each team was responsible to prepare the content not only for the expert but also for their peers. Regular progress updates should ensure that the group does not lose sight of the bigger picture and has assigned times to help each other across teams.
At the end of each topic a feedback round with students and instructors should provide insights for a potential fine-tuning of the next topic round.
We further assisted the participants by providing a clear daily structure with two progress presentations as intermediate goals, accessible team support and a coworking-friendly environment by dividing a seminar room into movable team

spaces with coffee and tea being available over the whole course time.

3.2 Description of the prototype

We came up with a course prototype held in summer 2017 with 19 participants (compare Fig. 1 to see the basic course structure), that were briefed about the concept and our expectations in a pre-meeting.
In randomly assigned teams, students were supposed to work through five topics successively, with three eight-hour days devoted to each topic. They brought their own laptops and had internet access through the university Wi-Fi. For students without a mobile device we provided a laptop for the duration of the course.
The first day was designed to get an initial understanding and perform further research about the assigned subtopic. In a plenary session, the outcome was shared with the whole group and the structure of the joint presentation drafted collectively.
On day 2 the collected information was intended to be condensed and accumulated into presentation slides and the final presentation rehearsed in the afternoon.
The resulting lecture composed of the four group presentations was presented to the expert in the morning of day 3 followed by a discussion. The rest of the day was used to conserve the acquired knowledge into a collective document (wiki). A voluntary seminar was offered at the end of day 3 after a feedback round.
To foster perseverance, each day students could earn a small proportion of portfolio points for collaboration and punctuality. Presentations and the prepared slides were graded as well and summed up with the points achieved in a final test at the very end of the course.

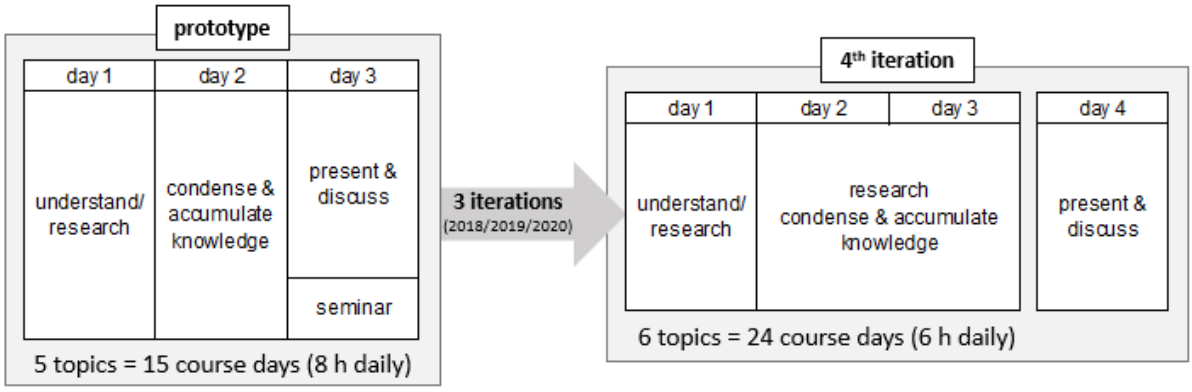

Fig. 1 Course structure development from prototype in 2017 to the last version in 2021. The prototype started with 3 days per topic (8 h daily) including an optional seminar and was iterated to the current format of 4 days per topic with a daily workload reduced to 6 h, including a course-free day before meeting the expert, if in accordance with calendar dates.

3.3 Lessons learned from the prototype

After having run the prototype of the course we learned that the concept itself worked out very well - vivid discussions with the experts have been observed as well as clearly positive feedback from the students stating that they have learned a lot about the topics and themselves and gained confidence in important soft skills, such as teamwork towards a hard and heavy deadline, as well as presentation and research skills. That matched the results of the self-assessments summarised in Fig. 2 (and more detailed in Fig. S1) and Fig. S2. Besides that, the motivating and clear course environment was praised repeatedly.

Nevertheless, eight hours a day for three weeks with only the weekend in-between was very demanding for most of the participants. It was not possible to do anything else than this course. It was also reported that the time per topic was not enough and students would rather have more time to digest the accumulated knowledge and learn more about the other subtopics. It was also requested to have more narrow-framed subtopics and topic specific guidance to not get lost during literature research. The optional day 3 seminar was attended by only a small subset of the group; non-participating students reported that they were just too exhausted to join. From the lessons learned during the prototype course we developed the basic setup of the course, which is still valid to date and described in section 3.4.

3.4 Basic setup of the course and its overall development over time

With the basic course structure, we created a “space to learn” where we assist student teams in preparing a presentation for invited field experts and fellow students by providing seed questions and topic related keywords. Within the now three days long research and content creation phase (6 h/day) we provide guidance whenever needed and a micro-timed schedule with organised time slots for information exchange between the teams (compare Table 1). On day 4 the lecture is presented to the invited field expert who detects and fills potential knowledge gaps and answers further questions. The expert also gets the opportunity to present their own research - now to a prepared audience that is confident to discuss the content. The learned content of all teams is then assembled into a document (wiki) and from 2020 onwards, read and enriched by all students via perusall, a social e-reader that should “turn the online reading assignment into a social experience to encourage students to engage with the material and with fellow classmates outside of class” [6].

When conducted in person (2018 and 2019), each team had an assigned team space within a seminar room. For regular meetings of the entire team, the room was transformed multiple times a day. During the research and content creation phase (day 1-3) instructors were present at preassigned times, and could be called in via digital communication. We started off with the course organisers being the only instructors, and then expanded successively by calling onto the help of other members of our research lab with more advanced topic-specific knowledge. Since 2020 we also provide an introduction lecture on day 1 to clearly define the level of expectation and learning goals.
When conducted online (2020 and 2021), we used a video-chatting service with breakout rooms for the sub-team meetings. As a noted benefit of the online format, we could expand our set of field experts internationally. We set up a channel in a messaging app to allow students to communicate with each other and instructors throughout the course. This kept in-course chatting away from other digital channels and allowed a clean differentiation of learning and leisure time. The collective student notes and presentation slides were created in a freely accessible online editor, allowing students to simultaneously work on the respective documents.
As due to the local pandemic situation the initially planned final exam could not be offered in 2020, we demanded homework instead. That consisted of finalising an assigned part of the knowledge collection (wiki) after it has been proof-read collectively. The handed-in documents were then marked individually. Having had the positive side-effect of further deepening the understanding of the topics, we decided to keep that substitute for further iterations.

Each tool contributed an essential component to the course communication. Note that students very much focused on this block course for its duration, and these tools essentially formed major elements of their work environment. As students are working in small teams, they can also help each other if aspects of these tools should be less familiar to some of them. A course page in our university Moodle system served as the central information platform with all details needed.

Table 1: tentative weekly course schedule at the beginning of the course with (intermediate) presentations framed in blue.

Day 1	Day 2	Day 3	Day 4
10:00 morning round	10:00 morning round	10:00 morning round	10:00 day/expert intro
10:10 overview lecture	10:05 prepare rough presentation	10:05 present improved presentation	10:05 presentation & discussion 10:05 student presentations 11:05 break 11:15 expert questions 11:35 expert research presentation 11:50 discussion / open questions
11:10 subtopic assignment	10:35 speakers present rough presentation	12:00 lunch break	13:00 lunch break
11:20 subtopic-team-research (I) solo research, lunch break, share with team and define tasks/sub-subtopics	11:50 prepare presentation (I)	13:00 finalize presentation, start team-wiki	13:40 complete team-wiki
14:00 subtopic-team-research (II) work on tasks/sub-subtopics, discuss presentation plan with mentor, combine tasks/sub-subtopics into presentation draft	13:00 lunch break	15:00 internal rehearsal and proceed on team wiki	15:20 answer survey
15:50 check out	13:40 prepare presentation (II)	15:50 check out	15:30 feedback
16:00 end of day 1	15:50 check out	16:00 end of day 3	16:00 end of day 4
	16:00 end of day 2		

3.5 Learning outcome

The experts commented extremely positively regarding the students' performance, both, about the presentation and the subsequent topic discussion and repeatedly renewed their commitment for the next years' course.

When looking at the self-assessed confidence levels summarised in Fig. 2 (and more detailed in Fig. S1), it is visible that participants greatly improved over the four course days in both the in-person and digital formats.

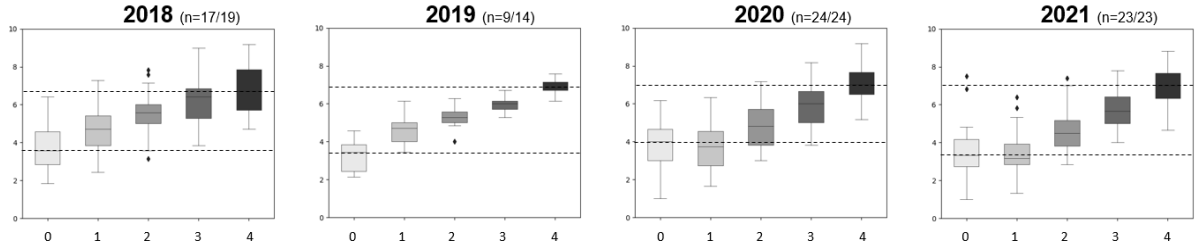

Fig. 2: Self-assessment of topic confidence levels before the course (0) and after each day (1 - 4) plotted as a mean over all topics. Each plot shows a year (2018 – 2021). Scale used on y-axis: "0 = absolutely no idea" to "10 = feel like an expert". The dotted lines highlight the median before and after the course.

Notably, when offering the course in-person the learning curve rose constantly while in the digital format in 2020 and 2021 confidence levels often dropped after the first day but rose even steeper within the following days. This features similarity to the Dunning-Kruger effect pointing out that people being unfamiliar with a topic tend to overestimate their initial knowledge [7]. Beside the influence of shifting the course into a digital format, we also provided a clear pre-lecture on day 1 confronting

participants with the expected depth of knowledge. Figuratively spoken, this might have pushed them from “Mount stupid” into the “valley of despair”, that however helped them to enter the phase of “enlightment” more easily within the next days. The non-observed drop after day 1 during the in-person version of the course might be due to the missing pre-lecture but also could be led back to the way data has been collected - students were indeed reminded to fill out the paper questionnaire regularly, but we observed some students filling it out not until the very end of the course, possibly resulting in distorted self-estimation.

CONCLUSION AND OUTLOOK

The increased topic confidence of the students and the positive feedback obtained by all stakeholders (students, instructors and experts) let us to conclude that we managed to create an environment to assist students in gaining theoretical knowledge in a new field within a limited period of time. Empowering students to benefit from invited field experts by providing a prior team mission (the final presentation) should be transferable to a multitude of disciplines and we highly recommend trying it out.

Based on our observations we plan the post-pandemic version to be hybrid by allowing students to work from the comfort of their homes during the research and content creation days and, on the presentation day, coming together in person to allow practising in-person presentation skills, strengthen the positive course atmosphere and intensify contact with the field experts through in-person experience. We intend to keep our digital work space as described above, and hope to maintain participation of international field experts digitally. We expect the resulting mixed in-person and digital presence of attendees during the presentation and discussion to require careful planning and set-up of technical infrastructure. Importantly, we will continue our weekly feedback rounds, which will plausibly lead to changes of these plans. We will remain open to adjust the opportunity space provided by this course to maximise the learning experience of the students.

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SUPPLEMENTARY MATERIAL

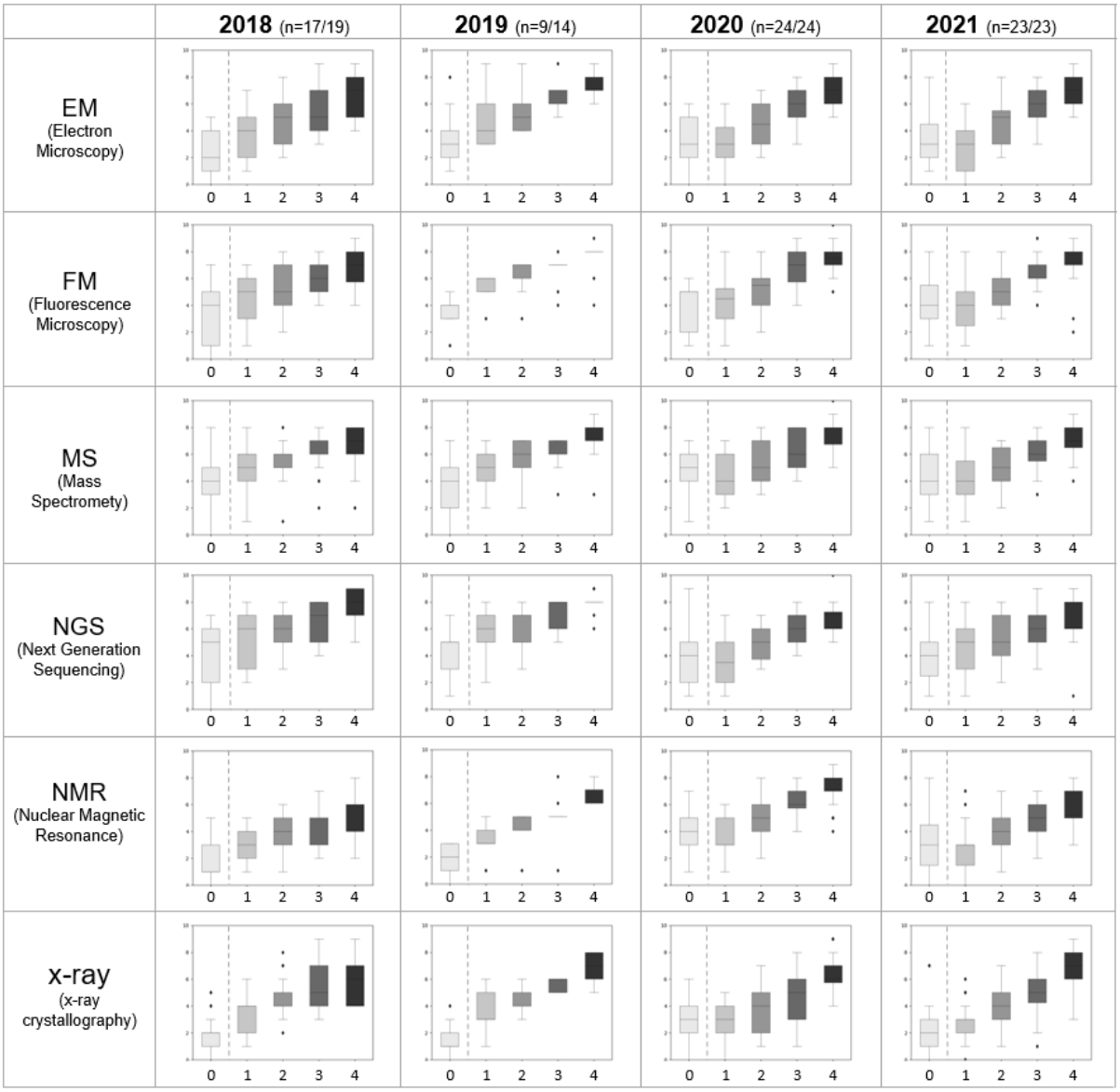

Fig. S1: Self-assessment of topic confidence levels before the course (0) and after each course day (1 - 4) for the years 2018 – 2021 with a scale on the y-axis of "0 = absolutely no idea" to "10 = feel like an expert".

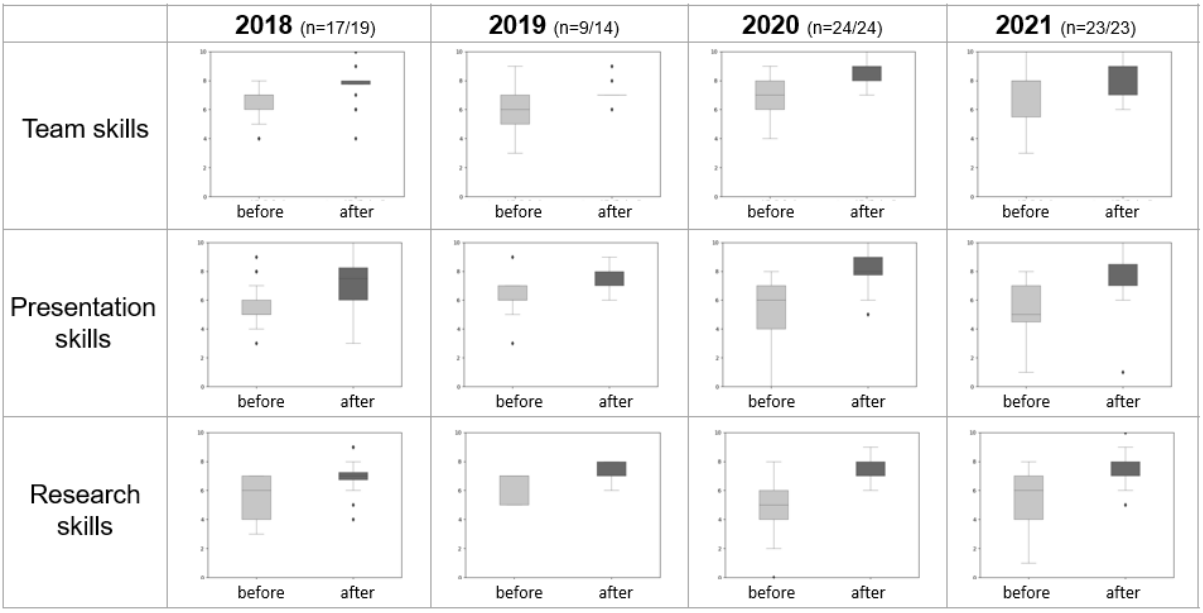

Fig. S2: Self-assessment of soft skills confidence levels before and after the course (team, presentation and research skills). Each plot shows a year (2018 – 2021) and the confidence level between 0 (lowest) and 10 (highest).

Advanced Bioanalytics 2018

Are you... ☐ female ☐ male ☐ other

What M.Sc. semester are you? ○ 0 (still in B.Sc.) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 and more

How would you rate your research skills **before the course**?

○ 0 (no idea where/how to start) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)

How would you rate your presentation skills **before the course**?

○ 0 (even thinking about presenting makes me feel stressed) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (presenting? No problem!)

How would you rate your team skills **before the course**?

○ 0 (teamwork makes me feel scared) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (no matter with whom - let's do it together!)

Please assess your level of confidence within the topic of mass spectrometry...

before the course:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 1:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 2:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 3:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 4:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)

Please assess your level of confidence within the topic of x-ray crystallography...

before the course:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 1:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 2:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 3:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 4:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)

Please assess your level of confidence within the topic of electron microscopy...

before the course:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 1:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 2:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 3:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 4:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)

Please assess your level of confidence within the topic of fluorescence microscopy...

before the course:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 1:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 2:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 3:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)
after day 4:	○ 0 (absolutely no idea)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9	○ 10 (feel like an expert)

Fig. S3a: Page 1 of the questionnaire used for self-assessment and feedback collection (paper format)

Please assess your level of confidence within the topic of NMR...

before the course: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 1: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 2: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 3: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 4: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)

Please assess your level of confidence within the topic of NGS...

before the course: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 1: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 2: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 3: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 4: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)

How would you rate your research skills **at the end of the course**?

0 (no idea where/how to start) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)

How would you rate your presentation skills **at the end of the course**?

0 (even thinking about presenting makes me feel stressed) 1 2 3 4 5 6 7 8 9 10
(presenting? No problem!)

How would you rate your team skills **at the end of the course**?

0 (teamwork makes me feel scared) 1 2 3 4 5 6 7 8 9 10
(no matter with whom - let's do it together!)

How would you rate the course (0=disappointing, 10=excellent)?

0 1 2 3 4 5 6 7 8 9 10

Would you recommend the course to other students? Why (not)?

What did you like?

What would you improve?

Fig. S3b: Page 2 of the questionnaire used for self-assessment and feedback collection (paper format)