Student guides: supporting learning from laboratory experiments through across-course collaboration

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ABSTRACT: We have observed that students often struggle with laboratory experiments. There is a high threshold to getting involved hands-on for fear of ruining an experiment, losing time, or breaking the equipment. More importantly, students have difficulty connecting the theory they learn in lectures and exercises with observations they make in the laboratory. As a result, it is difficult to formulate hypotheses, figure out what observations are needed, and make and interpret observations. We address this challenge by creating across-course collaboration between a basic- and an advanced-level *ocean and atmosphere dynamics* course, which run during the same study periods and are typically taken in subsequent years.

We train students from the advanced-level course to act as "guides" and to support groups of basic-level students doing laboratory experiments with the practicalities of running the experiments, making observations, and facilitating discussions about interpretations by asking open-ended questions. This benefits students from both levels: Basic-level students appreciate the help with new lab equipment and the supporting questions that help them make sense of observations. Advanced-level students understand the importance of questions in the learning process and realize how far they have come in understanding the topic in just one year. They report they would like to act as a guide again.

We reflect on which design criteria help make this across-course collaboration successful and where we still see room for improvement. Based on our experience and evaluation, we present recommendations for other teachers that might want to try a similar approach.

Keywords: ***Collaborative learning, laboratory teaching, experiential learning, Community of Practice, Co-creation***

1 INTRODUCTION

Students often experience difficulties applying theoretically taught concepts to the real world. Engaging students in experiential learning helps bridge the gap between theory and practice (Kolb, 1984). Experiential learning is often implemented in STEM teaching by including laboratory classes in the curriculum. We aim to create scaffolded hands-on learning situations (Wood et al., 1976) that fall into students' zones of proximal development (Vygotsky, 1978). The learning situations should be at a level of difficulty that is challenging but possible, where students make sense of new concepts, especially when supported by others.

We involve students as much as possible in shaping their learning (Cook-Sather et al., 2014; Bovill, 2020) to create conditions that enhance intrinsic motivation, such as experiencing competence, autonomy, and relatedness (Deci and Ryan, 2000). We strive to create a Community of Practice (CoP, Wenger, 1998; Wenger et al., 2002) where teachers and students learn together. In a CoP, there are different legitimate roles in terms of area and level of experience and expertise, goals, and responsibilities. Specifically, being on an "incoming trajectory," i.e., being new and on a steep learning curve, is a valued and legitimate role. Supporting students' learning through support from more advanced students is common (Crowe et al., 2014; Wheeler et al., 2017), but the more advanced students also learn from teaching (French & Russel, 2002). Bringing students from different stages of a study program together to learn from each other let students experience that it is normal and accepted not to know something and that subsequent attempts at shared sensemaking (Odden and Russ, 2019) can be a joyful and rewarding experience. We, therefore, engage a whole course of advanced students as part of their coursework and instruct them to act as "guides" for basic-level students in shared laboratory sessions.

This article focuses on how we can enhance learning related to practical tasks through collaborations between students at different stages of their education. We present a case study of student and teacher perceptions of the benefits and challenges of such across-course collaborations.

2 THE CASE STUDY

At the Geophysical Institute, University of Bergen, we educate students in atmospheric, ocean, and climate science. Students often find the physical processes related to large-scale fluid dynamics, such as the effects of Earth's rotation, challenging to imagine and understand. Therefore, in our introductory course, "*Physics of the atmosphere and ocean"* (GEOF105) which is taught in the fall semester, we developed a new laboratory session to give students hands-on practical experience with rotation and be able to describe the characteristics of a system in rotation compared with a system at rest.

In the fall semester, we also teach a more advanced fluid dynamics course, "*Dynamics of the atmosphere and ocean*" (GEOF213). The students in GEOF213 are more experienced with theory and practical experiments, typically taking it a year after they took GEOF105. Based on our understanding of how learning works and discussions with students, we expected that collaboration between students from GEOF105 and GEOF213 during the laboratory session would benefit both groups, and we designed an across-course collaboration on one laboratory session.

The GEOF105 cohort comprises 29 students from two different study programs (the "*Bachelor's Programme in Climate, Atmosphere, and Ocean Physics*" and the *"Energy Integrated Master's*"). The cohort from GEOF213 comprises 13 students from both BSc and MSc study programs (the "*Bachelor's Programme in Climate, Atmosphere, and Ocean Physics* " and the "*Master Programme in Meteorology and Oceanography"*). GEOF105 is taught in Norwegian, while GEOF213 is taught in English. 8 students from GEOF213 had previously taken the GEOF105 course, including the lab session. The remaining students from GEOF213 were a mix of international exchange students (4 students) and one Norwegian student that did their Bachelor's degree at another university. We consider the student groups from GEOF105 and GEOF213 as the basic-level and advanced-level students, respectively, and want to stress that we think of all of them are learners in the lab sessions, but for simplicity, we refer to them as "students" and "guides" in the following.

Before the joint laboratory session, we train the guides. First, they run the experiments and discuss different aspects of the observations and the accompanying theory. Second, they co-create a list of relevant questions they think are relevant and discuss how to best support the students in making observations and discussing the results. We emphasize that it is important not to answer all questions immediately but to facilitate the students' discussions by providing hints or asking new questions that help them find the answer themselves.

During the joint laboratory session, which we ran twice to keep student groups small, we paired groups of three students with one or two guides. Each group had its own set of equipment and ran the experiments in parallel with the other groups. The laboratory experiments were structured and scaffolded through a lab guide on paper that contained instructions, discussion prompts, and space for students to take notes and draw. The teacher was also available to support both students and guides.

We have run the collaboration session since 2020 and report on the evaluation from the third iteration, from autumn 2022. To evaluate this new form of across-course collaboration, we employed several different instruments:

- We used pen-on-paper questionnaires to survey the students' and the guides' perceptions of the experience.
- The students' laboratory reports contained a section with free-text meta-reflections.
- The experienced teacher of the course provided us with expert observations.

3 RESULTS

We report on student perceptions of this case study, first for the students and then for the guides.

3.1 Students

Students are generally satisfied with the experience of the lab session and their learning. All students fully or partly agree (90% fully, 10% partly) that the experiments helped them visualize a theoretical or abstract term (Fig. 1a). They also reported gaining a deeper understanding of the phenomenon and that the experiments increased their interest in scientific processes and motivation for further studies in their respective programs.

Including more experienced student guides had a self-reported positive effect on student learning, as seen in the substantially improved quality of laboratory reports. The guides helped the students feel safe in handling the equipment and secure necessary observations and contributed to a good discussion of the phenomenon (Fig. 1b, c). The guides also facilitated the discussions by asking questions that made the students reflect on different aspects of the experiments. The students largely agreed that the guides were helpful with this aspect (Fig. 1d, e, f). In most student reflection notes, we received quotes describing how students appreciated the guides. We provide a few quotes here as examples (translated from Norwegian):

> *"It worked great with a guide. Since we did not know what was going to happen, it was useful to have a guide that could pay attention to what we were looking at and point us in the right direction when we missed out on any observations. In previous courses, we typically had a few laboratory assistants covering the whole class. That increased the threshold for getting help compared with having a guide available during the whole session."*

> *"Having a guide from GEOF213 did help a lot in knowing what to look for during the experiment, which was helpful to get as much as possible from doing the experiment. Without the guide, it would have been easier to miss key points during the experiment."*

The students report being reluctant to take on the role as a guide the next year when they would take the advanced-level class (Fig. 1h). Only 28% of the students fully agreed, and equal amounts (35%) partly agreed or disagreed that they would like to take on the role as a guide.

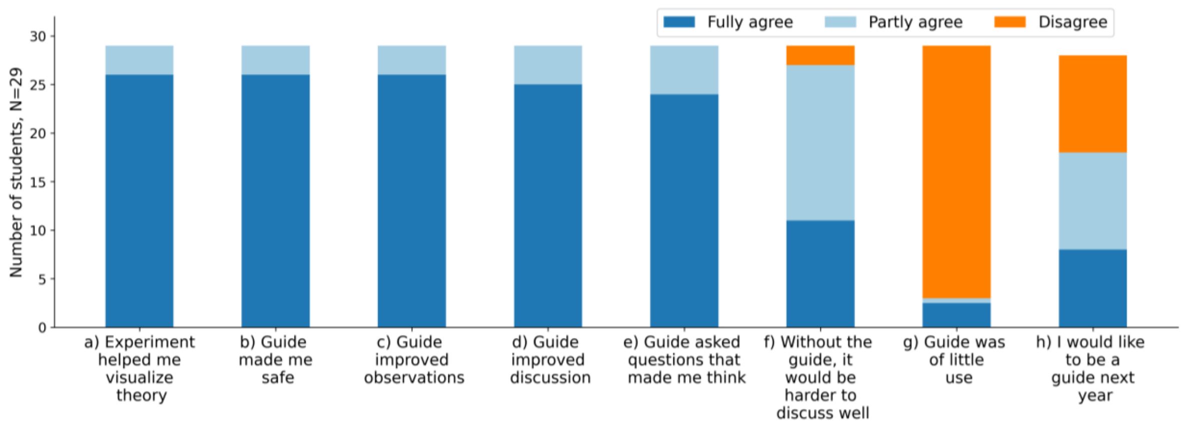

Figure 1. Students' survey responses concerning their learning and the role and value of the guides. According to the legend, the colors indicate the level of agreement with the quotes a-h).

3.2 Guides

Most guides reported learning new aspects of the experiment and becoming aware of their own learning during the past year through their role as guides (Fig. 2a, b). Most guides also reported no discomfort in their role as a guide during the lab experiments and would be happy to act as a guide again (Fig. 2c, h). Many guides were impressed by the students' level of knowledge and reported that the students could handle the discussion well without their help (Fig. 2g). However, most guides reported that the students benefitted from help to make good observations and be assured of what to do (Fig. d, e).

From the guides' free-text answers we received several quotes on the session, such as:

> *"It is a great opportunity to learn together."*

> *"It all worked well. It was fun to try to explain my knowledge in an easy manner that, at the same time, made the students think themselves."*

> *"It was a competent group [of students] with much independent discussion and good questions and observations. It was fun and I learned a lot."*

Some guides reported that it was hard to know what to say and what not to say. Some also report being stressed out by difficult questions from the students. This indicates that we could improve the student guide training and preparation for the task. The language was also pointed out as a barrier for those who did not speak Norwegian.

> *"It was frustrating to no be able to give direct answers, but very fun when the students arrived at the answers themselves"*

> *"It was tempting to answer, but important to let the students think themselves"*

> *"It is important to find the right timing to ask guiding questions. When they feel confused about the steps/outcomes of the experiment."*

> *"It is hard to give hints without giving the answer"*

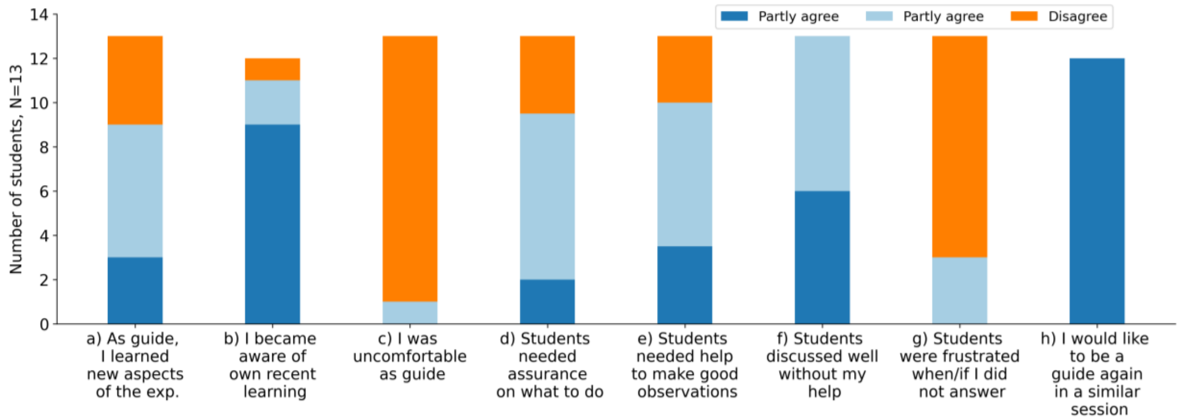

Figure2. Guides' survey responses concerning their learning and their role as guides. According to the legend, the colors indicate the level of agreement with the quotes a-h).

4 DISCUSSION

We observed a positive atmosphere with hard-working students and guides. Most groups worked efficiently with help from the guides. They obtained good and relevant observations, and their discussions were on topic. The atmosphere was more relaxed compared to earlier years, when we had no guides, and the teacher had to run from table to table to answer questions and supervise. In the first iteration of the across-course collaboration in 2020, we paid three volunteer advanced-level students to act as guides, thinking about how the basic-level students would benefit from the collaboration. However, the hired guides made us aware that they also benefited from the collaboration, and it was exciting to hear them reflect on their own learning and appreciation of the session. Based on their input, we decided to include the laboratory session as a part of the advanced-level course to let all students in that course benefit from the experience.

A laboratory session can be chaotic, especially when only a handful of teachers and assistants can help the students. Assigning a guide to each group completely changed the atmosphere in the room. The guides' roles are to oversee that the students do the experiments according to the instructions, make relevant observations, and facilitate the students' discussion of their results. At the start of the session, we convey this message to ensure that both students and guides know their roles. Both students and guides reported that the guides' assurance of the procedure was helpful (Fig. 1b, 2d) and that the guides ensured that the students made good observations (Fig. 1c, 2e). The students also appeared more confident in running the experiments compared to previous iterations of the session.

The students were comfortable asking questions and understood that the guides were not there to provide all answers. However, some students reported that it was confusing and difficult to arrive at the right answer. Some guides also reported that it was hard to handle all questions. Some questions were difficult, and it was tempting to provide answers instead of hints and new questions. However, several guides reported that seeing the students arrive at the correct answers was fun. The dynamic between students and guides varied from group to group, and some guides and students were less confident to participate in the discussions. Perhaps some guides – and then the groups they guided - would have benefitted from more thorough training and preparations of questions and answers. To equal out the levels of the groups, we could also run an evaluation session after the laboratory session, where we mix the groups and have them discuss their experiences, observations, and ideas about the theory. Many students are not used to doing experiments before learning the theory, and do not know how to deal with the unknown. In the evaluation session, the teacher could ensure the students get access to the same information and theory explanations. Also, if any groups get dubious results, they can discuss them with others and figure out if they did something wrong or if all groups arrived at the same result.

Most students fully agree that the guides improved their discussions (Fig. 1f). In contrast, the guides report that the students discussed well without their help (Fig. 2f). This could mean that the students felt overwhelmed by the experiments and did not notice how much they know already, or how they argue and discuss the results. The guides, on the other hand, have more experience. They see the valid points the students are making, and perhaps, they remember being in the student's shoes a year earlier and feeling like they know very little.

The only negative feedback we received was from students in the first (out of two) laboratory sessions, who had guides that did not speak Norwegian. We also observed dysfunctional collaboration in this group, with little communication between students and guides. There could be several reasons for the collaboration not working for this group. Firstly, both students and guides reported that the language was an issue. The students in this group were not comfortable discussing in English. Secondly, the guides were international students that had not done the basic-level course and had done the experiments for the first time during the guide training and preparation. Third, there could be cultural issues or issues related to personal characteristics among students and guides. After observing how this group's collaboration turned out, we made changes for the second laboratory session. Here, we asked the students to volunteer to have an English-speaking guide. The students who volunteered were confident in speaking English, and the collaboration worked well.

Interestingly, the guides were comfortable in their roles and would happily serve as a guide again (Fig. 2c, e), while many students reported that they would not like to be a guide (Fig. 1h). We speculate if the students are reluctant to act as a guide because they feel uncertain about the theory. On the other hand, the guides said (personal communication) that they had learned so much theory and gained much more practical experience since they did the basic-level course that they felt confident and competent to guide. They also learned new aspects of the theory while preparing to guide and realized how much they had learned recently (Fig. 2a, b), which made the whole task more interesting and rewarding. Perhaps a shared evaluation session between the teacher, students, and guides would have been good to implement. Then the students and guides could share their perceptions of how the collaboration benefited them, and we can co-create further improvements.

When the students had completed their tasks before the end of the session, we overheard several students-and-guide groups discussing other aspects of the experiment or guides sharing experiences from their studies. Both students and guides agreed (92% of guides and 96% of students) that the joint lab experiment offered a good opportunity to get to know students across cohorts.

5 CONCLUSIONS AND RECOMMENDATIONS

Our case study shows that combining a basic- and an advanced-level laboratory session to learn from and with each other can benefit both student groups.

Based on our experience with the across-course laboratory collaboration, we compile recommendations for how to design a similar learning activity.

Before the collaboration:

- Carefully consider the group/guide composition to avoid language issues or other factors that might be relevant for a good collaboration.
- Explain to the students that this is an experiential learning session where they have the experience first, then discuss the theory (the other way around from what they are used to).

- Train the guides for their role (explain the role, purpose, etc.), and let them work with the same materials the students will use later.
- Make sure the guides get "something extra," i.e., discussing the outcomes on a higher level when doing the experiments with them, but make sure they know what level is expected of the students.
- Help the guides to jointly collect "good questions" and discuss them carefully so that the guides feel competent to handle and facilitate the students' discussions.

During the collaboration session:

- Clearly explain the roles of the guides to everybody: the guides are not supposed to give all answers.
- Make sure there is sufficient allocated time so the students and guides can also talk about other relevant topics (e.g., upcoming elements of the study program or social events). This can help build an across-cohort relationship.
- Be available as a teacher and prepare to support both guides and students (the session is not something that runs all by itself).

After the collaboration:

- Facilitate a sharing and reflection session so everyone realizes that/what they have learned, and/or include reflection as part of, e.g., a lab report or a student presentation.
- Ensure the guides update the list of questions for next year based on their experience.
- Run a follow-up session in the basic-level course, where students can discuss the experiment and the relevant theory before submitting their laboratory reports. This can be helpful to equalize levels between groups and ensure that students have access to the same information or explanations of the theory.

ACKNOWLEDGEMENTS

The experiments build on the equipment developed by the DIYnamics project (Hill et al., 2018), and we would like to thank them for inspiring and helpful discussions. This work was funded by Olsens legat (buying the equipment, development of the initial materials, funding of initial guide cohort) and the CoCreatingGFI project, funded by the Norwegian Directorate for Higher Education and Skills (funding for A. D. Årvik).

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