Feedback and self-assessment in undergraduate student seminars in mathematics

Manuel Luethi[1]

Department of Mathematics, Tel Aviv University
Tel Aviv, Israel

Andreas Wieser[2]

Department of Mathematics, ETH Zurich
Zurich, Switzerland

Abstract

In this article we will discuss bachelor's seminars in mathematics at ETH. Most students (in these seminars) are neither used to individually preparing material from textbooks nor to discussing advances mathematics with fellow students.
As these seminars usually follow a single thread, it is often impossible to quickly catch up on the content of past lectures. Hence there is also the risk that students only focus on their own talks, which often results in badly aligned talks.
To overcome these problems, we implemented two tweaks to the standard setup. These are extensive meetings with the organizers and few mandatory exercises. We will evaluate the success of these measures and, where success is scarce, propose further measures to possibly address these problems.

1 Introduction

This article focuses on bachelor's seminars in Mathematics at ETH Zurich. We will discuss their intended goals as stated by the Mathematics department and their typical structure. As will become clear, this structure does in fact not align very well with the stated goals of student seminars. We will identify several challenges to the organizers and propose several measures to improve the structure with respect to the intended learning benefit. We will discuss several measures introduced by the authors in the past and discuss their (in)effectiveness and suggest certain improvements.

All bachelor students are required to attend a student seminar. The goal of a seminar is that the students independently study assigned material and put this across to their colleagues.[3] In particular, the students are assigned either one slot of 90 minutes or two slats of 45 minutes length for a presentation of the assigned material. The authors have experienced several difficulties in organizing these student seminars as opposed to regular lectures, some due to the established format, others due to the heightened difficulty of the material.

[1] manuelluthi@mail.tau.ac.il
[2] andreas.wieser@math.ethz.ch
[3] "In den Seminaren erarbeiten die Studierenden selbständig einen bestimmten Stoff und vermittelt diesen den Seminarteilnehmenden in einem Vortrag. Seminare dienen der Erweiterung des Grundlagenwissens oder der Vertiefung in spezifischen Fachbereichen, sowie der Übung des mündlichen Vortrags."
https://ethz.ch/de/studium/bachelor/studienangebot/naturwissenschaften-und-mathematik/mathematik/details.html [last accessed: 11/02/2020].

We will restrict our discussion to student seminars which consist of a sequence of connected talks. An alternative approach is given by seminars consisting of talks which do not rely on one another. Such a seminar circumvents some of the difficulties addressed below. Whereas this might be easier from an organizational perspective, we think that the type of seminar considered in this article offers a unique opportunity to collaboratively develop an understanding of advanced mathematics.

The main challenges we faced when organizing a bachelor's seminar were the following. The format typically requires a very focused effort of the students, namely the one or two time slots assigned for the talks and the preparation time. However, a seminar depending on a sequence of connected talks requires that the students keep focused throughout the whole course of the seminar. Also, the typical structure of a bachelor's seminar does not provide any opportunity for feedback or self-assessment, except for the presentations. As suggested by studies, e.g. [2], assessment and feedback over the course of the seminar are expected to result in better overall understanding of the topic.

The core topic of this article is the creation of opportunities for feedback and self-assessment in student seminars, without changing the general structure. Given the focus on independent learning and in particular in view of Section 4.5, we do not consider general classroom assessment techniques. Also, in light of an abundance of specific literature and our own ineptness, we will not elaborate on best practices with regards to feedback.

The article is structured as follows. In Section 2 we give a more detailed description of a bachelor's seminar and the expected audience, i.e. the context in which a bachelor's seminar takes place. We will identify a list of six main challenges we had to face when organizing a seminar, three of them specific to the format and three of them specific to the expected audience. In Section 3 we describe our own experience organizing a student seminar and list a few measures implemented to address the issues identified before. In Section 4 we first evaluate these measures and identify those which managed to improve the learning experience and those which failed to do so. Thereafter, we discuss additional measures that might help to overcome the still remaining problems we experienced.

2 Undergraduate seminars in mathematics

In this section we present the context in which such a seminar takes place, i.e. a detailed description of the typical student seminar as it is taught at the mathematics department of ETH and the composition of the audience. We identify three main challenges we faced as organizers arising from the expected composition of the audience. Afterwards, we identify three main challenges which arise from the format of a student seminar.

2.1 The purpose and format of a student seminar

As mentioned in the introduction, the aim of a bachelor's seminar in mathematics is that students independently prepare an advanced topic for presentation. In practice most seminars follow a text-book or a selection of articles and every week one or two students give a presentation of 45 to 90 minutes on selected sections of these references.

The detailed implementation might vary. Sometimes a written summary of the talk is required and recently some organizers have asked students to hand in solutions to selected exercises by the end of the examination period, i.e. towards the end of the semester break. In general however, no grade is assigned in the end and the students will either pass or fail based on the organizers' assessment of the quality of the talks. In addition, the number of credit points that the students can earn is fixed by the department at four ECTS-credits.

Using the taxonomy in [1] all undergraduate student seminars in mathematics have more or less the common objective that students acquire procedural knowledge in the form of methods and techniques regarding the assigned topic. In particular, the presentations, and in fact most presentations in mathematics, aim at providing the audience with an understanding of the nature and the applicability of these techniques.

2.2 Challenges resulting from the composition of the audience

The student seminars at the bachelor's level are run for students in their third year of study. Whereas the curriculum for the first two years is essentially the same for all students, in the fifth semester they are more or less free to choose their courses. All in all the background of the students might vary slightly if a seminar is run in the sixth semester. As organizers, we were free to impose further restrictions. We decided not to do so out of the idea that all students should be able to obtain a spot in a seminar, provided their studies are in agreement with the regulations. All in all, the background of the students was fairly homogeneous but due to the notoriously short supply of student seminars there probably was considerable variation in the degree of interest in the content of the course.

Up to that point, most of the students have only experienced teaching in the form of lectures with little to no active student participation. In addition to these lecture, the students usually were supposed to solve exercise sheets to accustom themselves with and to pick up on the content of the lectures. Data collected by the department of mathematics indicates that only a relatively small number of students spends time on the more conceptual exercises.

Usually successful participation in a course does not require the students to study any additional material besides their lecture notes and the official solutions of the exercise sheets. In fact, the curriculum taught during the first years is so packed that very few students find the time to study textbooks in addition to attending the regular courses.

During the first two years it is common practice to put strong emphasis on mathematical rigour. Typically, the instructors present mathematical statements and follow these up with proofs explicating all the intricate details. Learning the extent of rigour necessary for a full proof is of the utmost importance in mathematics. However, such attention to detail tends to blur the big picture and cover up the ideas behind the theory. When it comes to presenting more advanced mathematics, the discussion of such technical steps is therefore usually omitted in favor of new ideas.

Finally, we share with many colleagues the experience that students at ETH ask very few questions in class and discuss very little mathematics among each another. There have recently been several initiatives by ETH to get students to work in groups, e.g. the StudyCenter, and it remains to be seen how this platform affects interaction. At the time of writing, the authors are under the impression that the status quo largely remains.

From this we gather the following three challenges resulting from the composition of the audience:

1. The students will consult textbooks and other sources in order to deepen their understanding of the assigned material.
2. The students learn to narrate mathematics at an advanced level.
3. The students get used to actively discussing mathematics.

2.3 Challenges resulting from the format

A first problem the authors experienced in student seminars is that due to bad incentives the students focus their effort solely on their own presentations. Whereas in a standard course this is merely a problem for the inactive students and might lead to a depressing experience for the lecturer, it becomes a major obstacle to a successful seminar. The topics are often related and a lack of understanding of one topic often prevents the understanding of the topics to follow. Furthermore, a lack of understanding for the tools presented in earlier talks is likely to lower the quality of ones own presentation of a later topics. The tendency of focussed attention is further amplified by the notoriously packed schedule of students at ETH, which is also how some of the issues mentioned in Section 2.2 arise.

Whereas the students supposedly spend a lot of time studying the content of their own talk, they spend the majority of the semester listening to other students' talks. However, in view of the results compiled in [5], it is unlikely that the students learn much from attending other students' talks without practice. Moreover, without any opportunity to practice, students have no means to tell whether they understand the topic.

One less obvious problem experienced by the authors is the students' tendency to present to the organizers instead of the fellow students. This is very unfortunate, as usually the organizers are already quite familiar with the material and at that stage – as will become clear later – know already how well the student giving the talk has understood the topic. Still, many students seem to consider the presentation as part of an examination.

We summarize the above discussion by identifying the following list of challenges resulting from the format:

1. The students will have an incentive to be involved throughout the whole semester.
2. The seminar continuously offers the students opportunities to assess their understanding of the content of the course.
3. The students teach one another.

We note that, unlike in Section 2.2, these challenges are not specific to mathematics seminars. It is the experience of the first named author that the same challenges arise in seminars in social sciences and humanities.

3 The authors' approach to a bachelor's seminar

We will now discuss the seminar taught by the authors in spring 2018. We first present its general structure and the choice of content. Then we will discuss the teaching interventions made in comparison to the typical structure which consists of delivering 90 minutes of presentation.

Our seminar broadly followed the typical structure outlined in Section 2.1. The main idea was to find an advanced research article – in this case an article by Eskin and McMullen [4] – the content of which could be simplified to one or several special cases that can be examined using the elementary tools available to the students at that level. In general, it might be reasonable to think of a not too difficult article, suitable for a bachelor's thesis.

The intended role of the organizers was to divide the general theory discussed into its basic ingredients and to serve as experts the students could (and should) consult in order to put these ingredients into context. The guiding vision was that the students would spend the seminar on first building up the prerequisites together, each student specializing on a small part, and then apply the theory developed in several special cases. Whereas this would mean

quite a bit of work for a single mathematician at that level, this can be done in collaboration with reasonable individual effort.

Corresponding to the criteria of a student seminar, every student was required to give two talks throughout the semester, 45 minutes each. These two talks were the core assessment on which we based whether the student passed or failed. Given that the student did follow up on our requirements clarified in the meetings discussed below, attended the class regularly and showed a "reasonable" effort on the additional measures to be discussed, the passing was granted.

The first two talks of the course were held by the organizers, in order to set a precedent regarding the atmosphere and the form of the talks expected; cf. Section 2.2. To our knowledge, this is not standard procedure but certainly not new either.

3.1 Meetings

For each talk we organized two meetings between the students and the organizers. The first meeting took place approximately a week before the talk, and it served as an opportunity for the student to discuss the assigned literature with the organizers. This meeting was a first opportunity to assess the material consulted by the student and assist in the search for additional sources if needed. Moreover, this was an opportunity to give the students extensive feedback regarding their understanding of the topic. During this meeting, the assigned material was discussed very thoroughly and the focus points were identified. This was supposed to help the organizers emphasizing the importance of ideas over technicalities and help the students understand the story to be told. Naturally, if taken seriously these meetings take quite a bit of time, and we scheduled at least a full hour for each student. Furthermore, the organizers took care that at the end of the meeting the students were well aware of the structure and the content of the talk that was expected. After the meeting the students had a very concrete list of still open problems that needed to be answered to complete the understanding of the assigned material.

Between the first and the second meeting, the students were expected to produce a talk from the material. The second meeting took place two to three days before the talk. For this meeting, the students were expected to bring along an almost finished presentation. The second meeting was explicitly communicated to guarantee that the students' talk corresponded to the organizers' expectations.

3.2 Mandatory exercises

In addition to the regular two talks, we assigned two exercises to every student, which they were supposed to hand in before the end of the semester. The exercises were assigned to pairs of students with the intent that they collaboratively attempt to find a solution, giving them ample opportunity for discussion. The content of these exercises was complementary to the talks, i.e. they were selected so as to ensure that any solution would combine on methods from other students' talks instead of being direct applications of the topic the student talked about him- or herself.

The exercises were made available in two groups, one in the beginning of the semester and the other one after the first half of the semester. It was the task of the students to figure out whether or rather when a talk was of particular interest to the solution of the exercises, therefore motivating the students to try to keep up with the content of the course throughout the whole semester.

Besides keeping the students involved with the subject of the course, these exercises offered the students opportunities to test their understanding of the topic. The organizers – as always

– were available for individual discussions and questions about these exercises. The exercises were officially considered difficult and failure to solve them would not directly result in a failing grade. However, a "serious attempt" at finding a solution was required.

This measure had in a similar fashion already been implemented in earlier seminars by one of the authors. To our knowledge it is not common practice to require the students to solve any exercises in student seminars.

4 Discussion and additional measures

In this section we evaluate the approach to teaching a seminar taken by the authors. To this end, we will outline the successes and shortcomings of the additional measures regarding meetings and exercises in Sections 4.1 and 4.2 respectively. Let us briefly summarize our findings. Even though the seminar described in Section 3 was quite a success, both from the authors' perspective as well as judging by the students' feedback, the takeaway for the question underlying this article is that mastering the challenges identified in Section 2 requires more creativity. Whereas the frequent interaction between students and organizers seems to be extremely useful, the exercises assigned to groups of students neither served as a means of self-assessment nor did they lead to additional collaboration among the students.

Having identified several issues of the tweaks implemented by the authors, we use Sections 4.3 to 4.5 to propose other means to address the challenges at hand in the remaining parts of this section. It is important to keep in mind that the maximum number of ECTS credits obtainable is fixed.

4.1 Effectivity of the meetings

The organizers made a strong effort to keep the meetings with the students relatively informal and shape them as a discussion between them and the organizers. If the opportunity presented itself, we took time to think about problems together, even if the strategy on how to solve a problem was clear to us. It was our experience that this was the quickest way of getting the students involved in a discussion and in particular of establishing a collaborative atmosphere. These occasions were an opportunity to approach a problem by first formulating a strategy and then checking whether this strategy works. This also helped putting the focus on ideas instead of technicalities.

The second meeting has proven very helpful to both the organizers, who could be reassured that the talks would cover the desired topics, and to the students, who thereafter could be confident in having prepared their talk according to the organizers' expectations.

All in all it is our experience, also from feedback from the students, that the two meetings before a talk were greatly appreciated and indeed served the purpose of providing extensive feedback as well as setting a precedent in terms of an atmosphere of collaboration.

4.2 Effectivity of the exercises

The exercises turned out much less effective. On the one hand, the organizers were satisfied as students facing difficulties ended up contacting the organizers and made great use of the opportunity to discuss the exercises outside the classroom. On the other hand, they do not seem to be an appropriate tool to keep the students' attention or to help with self-assessment throughout the semester. In general it was our impression that the very good students would solve the assigned exercises as intended, once the required tools became available, whereas the students that were struggling would delay the exercises towards the end of the semester.

This means that the exercises help keeping those students involved which are more likely to not neglect the seminar anyway, whereas the struggling students don't use the chance to assess their understanding of the topic. It seems that we were trying to achieve too many goals with one single item. In this way we were violating a core principle of constructive alignment. In this instance we gave the students exercises based on the material of half the course in order to self-assess their week-to-week progress.

With regards to assigning the exercises to pairs of students, it was our impression that the students immediately split up the duty and worked on their share by themselves. Assigning exercises to groups of students in this form does not seem to lead to collaboration.

To summarize, it seems that this tweak leaves ample room for improvement. As a slight modification to improve collaboration in solving exercises, one could consider a common problem session. In such a problem session, the students would be divided in groups of two or three. Each group would be given an exercise selected by the organizers so that it suits and complements the knowledge of each student in the group. The students would then start working on solving the exercise together where it is not assumed that they complete the exercise at the end of the session. The hope is that the initially organized collaboration motivates the students to continue working together on the given exercise.

4.3 Notes

To introduce a collaborative effort and an additional source of feedback, we suggest the collective production of a set of notes. Each student would be required to produce a formal write-up of two talks held by other students in an effort to produce an expository paper. At the end of the seminar, the students will have produced collectively an introduction to the topic, which is to be reviewed by the organizers and can be published online. In order to be able to produce the write-ups of the talks, the students will have to pay attention to the fellow students' talks. They should also be interested in interfering and asking questions when the talk is unclear on a crucial point.

The speaker should be required to review the write-up. In this way, we induce two forms of feedback. The speaker gets the opportunity to self-assess his or her performance from the write-up by the fellow student, and the fellow student will receive feedback on his or her understanding of the topic from the speaker. In addition, the organizers should assign time to meet and discuss the write-ups with the students towards the end of the semester.

Producing the write-up should require an additional effort of at most four hours, which from our experience should not conflict with the maximum of four ECTS credits obtainable for passing the seminar.

4.4 Quick exercises and open questions

In order to provide the students with the chance to assess their understanding of the material on a regular basis, the organizers could think of one simple exercise per week for the students to try their hands at. They could provide an example of a solution through which the students can assess to what degree they were able to solve the exercise; cf. [2, 6]. In addition, the organizers could require each speaker to pose during his or her talk an open question, which the students think about individually for approximately one minute and which they then briefly discuss in groups of two. The organizers could help the student come up with a good question; cf. the strategies outlined in [3]. Both of these measures are supposedly non-graded problem-solving tasks.

4.5 Get rid of the organizers

As outlined in Section 3.1, it is the authors' experience that the meetings are extremely valuable sources of feedback for the students. In fact, by the end of the second meeting the organizers are almost fully able to tell whether the student will give a good presentation. With respect to the last challenge stated in Section 0, it might be an option to run the seminar in the absence of the organizers. Instead, the organizers could put the main emphasis on the second meeting. This would then take place a very short time before the seminar meeting. There, the organizers and the student go through the planned talk in detail to ensure that the focus is set correctly. Afterwards, the student would be required to give a fifteen to twenty minute snapshot of the talk, starting from a point chosen by the organizers. After this the presence of the organizers in the seminar is only required in the beginning and at the end of the talks, to ensure that the participants are present, and in cases where it is expected that the speaker is still not able to present the topic. It is to be expected that the absence of the organizers during the talks would cement the understanding that the students are talking to one another.

5 Conclusion

While the authors would still stick to the measures outlined in Sections 3.1 and 3.2, namely extensive meetings and mandatory exercises, it seems advisable to look for additional ways of providing feedback, for example in the forms discussed in Sections 4.3 and 4.4 . This way we provide the students with an easy way to assess their progress on a weekly basis as well as a total of three times two, i.e. six, opportunities to deeply analyze their understanding of the topic:

- The two talks, which are the main challenge for the course.
- Two difficult exercises as described in Section 3.2, which review and connect the concepts discussed in class and possibly recast them in a specific application.
- Two reviewed sets of notes.

On average this corresponds to a non-graded assessment every two to three weeks. Two of them, the exercises, are documented problem-solving tasks. Another two, the write-ups, are knowledge-probing tasks. Altogether this should lead to more active learning and a deeper understanding of the topic of the course.

The tweaks presented above are not constraint to mathematics. It may seem that except for the formulation of exercises these measures can be applied in every area of study, most certainly in the more technical areas. In some sense the difficult exercises as presented in Section 3.2 are also common practice in student seminars in humanities, where they take the form of term papers. It is however common practice to have students choose the topic of the term paper, i.e. formulate the exercise, on their own. This reflects that many student seminars in humanities formulate the ability to develop a research question as the main learning objective. This is an objective of much higher order and it might be of interest to introduce additional assignments of intermediate complexity as discussed in this article.

Acknowledgments

We would like to thank Menny Aka and Manfred Einsiedler for several helpful discussions on teaching mathematics and also for the occasions to run student seminars under their name. We also want to thank the students who attended the seminar for making it such a great experience. The first named author would like to thank Karin Brown for her very helpful course on teaching practices. We thank the referees for many helpful comments.

M.L. acknowledges the support of the Swiss National Science Foundation through grant 200021-178958 as well as Israeli Science Foundation through grant 1483/16. A.W. acknowledges the support of the Swiss National Science Foundation through grants 200021-152819 and 200021-178958.

References

[1] Lorin W. Anderson and David A. Kratwohl (Ed.). A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives (Complete edition). New York: Longman, 2001.

[2] María T. Carrillo-de-la Peña et al. Formative assessment and academic achievement in pre-graduate students of health sciences. Adv. in Health Sci. Educ., 14:61–67, 2009.

[3] Robert L. DeHaan. Teaching creative science thinking. Science, 334:1499–1500, December 2011.

[4] Alex Eskin and Curt McMullen. Mixing, counting, and equidistribution in Lie groups. Duke Math. J., 71 (1):181–209, 07, 1993.

[5] Scott Freeman et al. Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences, 111 (23):8410–8415, 2014.

[6] David J. Nicol and Debra Macfarlane-Dick. Formative assessment and self-regulated learning: a model and seven principles of good feedback practice. Studies in Higher Education, 31:199–218, 2006.