



Heat and Flow in times of Corona

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Abstract

Dieser Artikel beschreibt den Aufbau des Kurses „Heat and Flow“ im zweiten Jahr des Bachelor-Studiengangs Maschinenbau der Technischen Universität Eindhoven. Vor der Coronapandemie und der damit verbundenen Sperrung wurden verschiedene Maßnahmen ergriffen, um die Erfolgsquote dieses Kurses zu erhöhen, die früher sehr niedrig war. Insbesondere wurde neben den normalen Kurselementen von Vorlesungen, Instruktionen und Übungen eine vollständige Online-Version des Kurses entwickelt. Auf diese Weise werden Studierende mit unterschiedlichen Lernstilen bedient. Um die Studierenden zu motivieren, lange vor der Prüfung genügend Zeit für den Kurs zu verbringen, wurde ein System obligatorischer Fortschrittstests entwickelt. Ein gutes Ergebnis für jeden Test ist die Voraussetzung, um die Prüfung des Kurses zu bestehen. Die Anzahl der Versuche für jeden Test ist innerhalb eines bestimmten Zeitrahmens unbegrenzt. Die Kombination beider Entwicklungen verbesserte die Erfolgsquote des Kurses erheblich. Während der Coronapandemie wurde das gleiche System aufrechterhalten, indem alle Elemente des Kurses synchron, jedoch online angeboten wurden. Die schriftliche Prüfung wurde durch eine online beaufsichtigte Prüfung ersetzt. Die Studierenden waren mit dieser Art des Unterrichts zufrieden, aber die Teilnahme an den Übungsstunden war sehr gering. Sie kann verbessert werden, indem sie in kleinen Gruppen mit jeweils einem persönlichen Tutor organisiert werden.

This paper describes the set-up of the course Heat and Flow in the second year of the bachelor program in Mechanical Engineering of Eindhoven University of Technology. Before the corona pandemic and its associated lockdown, several measures have been taken to increase the success rate of this course, which used to be very low. In particular next to the normal course elements of lectures, instruction and exercise sessions, a complete online version of the course has been developed. In this way students with different learning styles are served. In order to stimulate students to spend sufficient time on the course well before the exam, a system of compulsory progress tests has been developed. A good result for each test is a requirement to pass the exam of the course. The number of attempts for each test is unlimited within a certain time frame. The combination of both developments significantly improved the success rate of the course. During the corona pandemic, the same system was maintained by offering all elements of the course in a synchronous way, but online. The written exam was replaced by an online proctored exam. Students were satisfied by this way of teaching, but the participation in the exercise sessions was very low. This can be improved by organizing them in small groups, each with a personal tutor.

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1. Introduction

In this contribution I will describe the teaching and assessment methods used in the course Heat and Flow of the second year of the bachelor program Mechanical Engineering at Eindhoven University of Technology during the corona pandemic in the Spring of 2020. In order to put this in the right context I will first present the history of this course in section 2, where I will in particular show how the course has been changed over the years to increase the success rate of the course. Next, in section 3, I will detail the teaching methods applied in academic year 2019-2020 during the corona pandemic, when all on-campus teaching was not permitted due to the lockdown. In section 4 I will discuss the lessons learned from this experience and the measures taken in the next academic year, when the corona measures were partly relaxed, to improve teaching and learning. In the final section the most important conclusions are presented.

2. History of Heat and Flow

In 2012 Eindhoven University of Technology (TU/e) started a completely new set-up for all bachelor programs, named Bachelor College. This was both meant to increase the number and the diversity of students and to improve the study success. One of the measures taken to increase the study success was a change in the size of all courses from 3 EC to 5 EC, in order to reduce the number of exams (1 EC corresponds to a study load of 28 hours and one full year has 60 EC).

For this reason two existing courses, one on transport phenomena and the other on heat transfer, were combined to form the new course Heat and Flow in the fourth quarter of the second year of the Mechanical Engineering program. From the start, I have been the responsible teacher for this course and I give the lectures on the flow part. The teacher of the heat part was already the responsible teacher for the old course on heat transfer, while I was the teacher of a first-year course Introduction to Heat and Flow. The flow part of the new course was partially based on another existing course on physical transport phenomena. The topics treated in the course are:

- Repetition of differential operators, material derivative and cylindrical coordinates;
- Integral conservation laws for mass momentum and energy and Bernoulli's equation;
- Derivation of continuity equation and Navier-Stokes equation for incompressible flow and some simple solutions;
- Scaling and similarity;
- Flow in pipes, around objects and in boundary layers, including the Blasius solution for laminar flow and separation;
- Basic mechanisms for heat transfer, conduction, convection and radiation;
- Steady and unsteady heat conduction;
- Convection and thermal boundary layers;
- Basic definitions for radiation and radiative heat transfer.

The course is mandatory for all students of the bachelor Mechanical Engineering, and elective for a smaller number of students of the bachelor Sustainable Innovation and for a group of students that follow a premaster program after having finished a bachelor at a university of applied sciences. The total number of students enrolled in the course is typically around 350.

In the course we loosely follow a textbook [1], but for some parts we made our own lecture notes and we developed a book of exercises, partially composed by ourselves and originating from other courses and partially taken from a number of different textbooks. There are not so many textbooks that combine fluid mechanics and heat transfer and are suitable for students at bachelor level. The textbook we selected is one of the few. It has some drawbacks, in particular the combined use of SI and American unit systems. The main advantage of this book is that the level of mathematics required to understand the theory is not too high for our students.

Initially Bachelor College had the requirement that the final exam of every course counts for at most 70% of the final grade of the course. Interim exams count for the remainder of the final grade. The idea behind this is to encourage students to start learning sooner than a few days before an exam in order to increase

the success rates. The first three years the course was taught we had one or two interim exams to comply with this requirement. However, it turned out that the effect of this was rather opposite to what was intended. Students with a bad grade for the first interim test were demotivated by their result and usually did not pass the course. Apart from this, it is a big task to organize and grade interim exams for such a large number of students.

As soon as the requirement was lifted, we stopped the interim exams and replaced them by formative assessment in the form of digital quizzes, one for every topic of the course, so that students could monitor their progress. However, only a minority of the students actually made these quizzes and the pass rate of the course did not change, but remained around 40% after the first exam.

By that time, around 2017, our university more and more promoted the use of blended learning by combining various learning methods for a course. It is well known that some students prefer to learn individually at the time and place they want, while others prefer the structured way of learning by attending lectures and exercise sessions at the time they are scheduled and like to work in a small group of students on an exercise [2]. For that reason we made the plan to develop an online version of the course and offer the students the choice to attend all scheduled activities or use the online version of the course.

For all elements of the course an online variant was made. The course consists of three elements:

1. The first element of the course are the lectures. The course consists of 13 lectures of two hours each. The online variant of each lecture is a document with a short summary of the course material and links to video lectures selected from YouTube. We asked the authors of the movies permission to use their material in our course. In this way we can download it and still use it in case a video is no longer available in YouTube. All authors responded very quickly and positively to our request and some of them asked to be kept informed about our online efforts.

2. The second element of the course is the so-called instruction, in which the lecturers make a number of selected exercises on the blackboard to give extended examples of each type of exercise that is important and of exam level. Usually there are seven instruction sessions of two hours each. The online variant of the instruction is a set of pencasts in which the same example exercises are treated and explained. Figure 1 shows a still from a pencast.

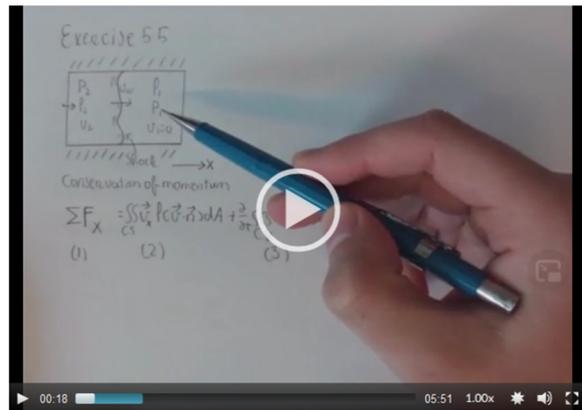


Fig. 1: Still from a pencast. The pencast also has sound. The video is available at <https://youtu.be/4xrsQbQUEmE>

3. The third element of the course is the so-called guided self-study (GSS), where students work individually or in small groups on exercises. A number of teacher assistants and the lecturers are present to answer questions. Attendance of the GSS is usually rather low, between 25% and 30% and shows a decrease towards the end of the course. Usually there are seven GSS sessions of two hours each. The important aspect of the GSS is the possibility of feedback, which is more difficult to give online. For this we used an online assessment system called Cirrus [3]. A number of exercises have been composed in Cirrus, usually with random numbers. The students can provide their answers and in case of a wrong answer automatic feedback is given. An example of automatic feedback is shown in figure 2. Not only numerical questions are possible, but also multiple-choice and mathematical questions, in which the students have to enter formulas.

FILL IN THE MISSING VALUE(S)

2



The Bernoulli's law needs to be applied twice in this case. Once over the manometer and once over the fan itself. Note that there is no velocity difference in the manometer, hence the pressure difference, Δp_m , is equal to the pressure due to the height difference of the water, $\rho g \Delta z$.

Subsequently, there is no height difference over the fan. Hence, the pressure difference due to the velocity, $\frac{1}{2} \rho_{air} \Delta v_{fan}^2$, is equal to the pressure difference, Δp_{fan} .

And finally, it holds that $\Delta p_{fan} = \Delta p_m$. Now, solve this for the Δv_{fan} and assume that the velocity in front of the fan is zero (holds if you draw your control volume correctly).

Hint: Be aware that you are working with two different densities. Do not mix them up.

430



Power in fluid dynamics is expressed as $P = \Delta p Q$. Both Δp and Q are obtained at the first part of this exercise.

$Q =$ m^3/s

$P =$ W

Fig. 2: Example of automatic feedback on wrong answers to digital exercises in Cirrus.

The first two elements of the online version of the course are available in our learning management system Canvas. In order to develop everything, two teaching assistants have been employed for a total of 800 hours. The financial means for their salaries have been provided by the educational innovation fund of Eindhoven University of Technology. The teachers of the course checked the video material selected, the pencasts and the online exercises. A teacher supporter from the university supported them in setting up a user-friendly organization of the course in the learning management system.

The material in Canvas is organized in the 13 lectures of the course and provides links to the Cirrus exercises. At the end of each lecture an online quiz has to be made with sufficient result (80%) in order to get access to the next lecture. In this way we ensure that students spend sufficient time on each lecture.

Finally, every lecture has a discussion forum that enables students who follow the online version of the course to ask questions. Usually, teacher assistants answer these questions, but in some cases also other students respond.

We tested the first version of the online course on a group of six students, who failed the exam several times. They provided feedback and were offered an extra exam directly after this test. Most of the feedback was positive and in a few cases they even suggested better video

material than selected by the teacher assistants. They all passed the extra exam that was offered to them with remarkably high grades.

This showed that the online course prepares well for the exam and in this sense satisfies one of the criteria for constructive alignment [2]. However, the students participating in the test could be monitored well, because of their small number, and they were all very motivated because of the extra opportunity to pass the course, which was for most of them the last hurdle to finish their bachelor program.

We knew that for the normal group of students the incentive to keep on track during the course would not be so high. Therefore, we decided to develop an assessment method that forces the students to spend time on the course well before the exam without the disadvantage of interim tests that a bad result cannot be repaired [4].

We found a solution in the form of so-called progress tests. During the course students have to make three progress tests which are offered digitally in Cirrus. Each test can be made as often as they want, but within a limited time span of about a week. Automatic feedback is provided on wrong answers in the form of a reference to the corresponding theory. Students need a score of 80% or more for each of the three tests to obtain the grade for the final exam. They can work together on the tests, but random numbers are used, which

makes copying of answers useless. The first progress test already starts in the first week of the course and is about the prior mathematical knowledge required in the course. The second progress test is about lectures 2-5 and the third and last progress test is about the basic mechanisms of heat transfer and steady and unsteady heat conduction. Each test consists of ten questions. Most of them are numerical questions and a few others multiple-choice questions. The first test also has a number of mathematical questions in which the answer is a formula. However, this type of question is rather sensitive to errors; for example multiplication signs between two symbols should not be forgotten.

This method of assessment is not in accordance with the regulations of Bachelor College. Therefore, we asked permission for this pilot and also consulted the examination committee of our department and the students in the program committee, who all agreed with this pilot.

The first time the new system was in use was in the Spring of 2019, so one year before the corona pandemic started. Our main goal was an improvement of the success rate of the course. Success rate can be defined in various ways, but no matter which definition we used, the increase of the success rate was significant. The success rate of all registered students increased from 34% in 2017 and 2018 to 50% in 2019. Quite a number of registered students decide to postpone the course to a later year. Therefore, it is better to consider the success rate of all students that did a serious attempt in the exam (score of 15% or more). This number increased from 48% to 70%.

The distribution of exam grades is shown in figure 3 for the years 2017-2019. The grades range from 0 to 10, where 10 is the maximum and 6 is sufficient to pass the course. The figure shows that the distribution of grades in 2019 has a shape closer to a normal distribution. The almost absence of very low grades in 2019 has a different reason, but this does not influence the conclusion about the success rates, since the very low grades are not taken into account in the success rates.

Students who did not pass the requirements of the progress tests, could make them again in

the weeks between the first exam and its resit. Only one student participated in the first exam without satisfying the requirements and he or she passed the requirement later and then received the exam result. Some additional students only participated in the resit and made the progress tests after the first exam.

During the standard evaluation of the course a remarkable observation was that the students indicated that they have spent less time on the course than in the years before. This clearly shows that the progress tests help the students reach the learning goals of the course. The evaluation also showed that students are satisfied with the feedback offered by the progress tests (score 3.8 on a scale of 1-5). The progress tests not only help the students know what to learn, but they also result in a better spread of the workload over time.

The results of our pilot stimulated teachers of other courses to also change from interim courses to digital progress tests in their courses. At present all major courses in Mechanical Engineering in the first year and another second year course use this assessment method, and a third-year course will follow in the next academic year.

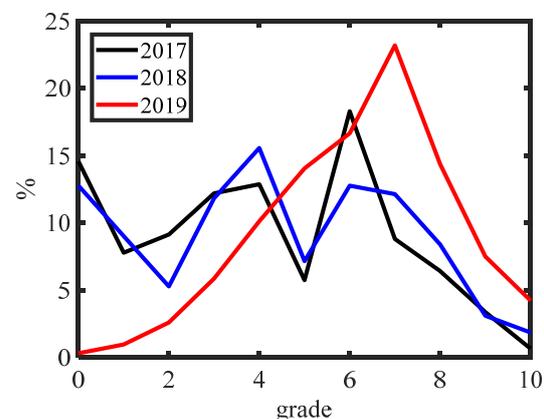


Fig. 3: Distribution of grades of the first exam of Heat and Flow in the years 2017-2019. A minimum grade of 6 is required to pass the course.

The details of the system of progress tests differ from course to course, as for instance the number of tests and the criteria used to pass them. In the near future we will propose to adapt the regulations of Bachelor College to allow progress tests for all courses. Several other departments showed their interest in this system, as it appears a better method to

engage the students during the time a course is running and it does not result in procrastination behavior.

3. Heat and Flow during corona pandemic

When the corona pandemic reached the Netherlands in March 2020 and the lockdown was announced, the executive board of our university decided to cancel all teaching activities during one week to give the teachers time to change their courses to an online format. For some courses, which required experimental facilities, this was not an easy job, but for all courses organized by our department an acceptable solution was found, for instance by using and analyzing experimental results from a previous year instead of performing new experiments.

Many teachers decided to teach from home, using either Microsoft Teams, or the learning management system Canvas. Others used the livestream facilities in the lecture rooms at the campus, which were still available, or recorded their lectures in the studio at the campus or at home.

A bigger problem was to find a solution for the exams that were scheduled already three weeks after the start of the lockdown. For some courses, in particular those with a small number of students, it was possible to replace the written exam by an assignment. For courses with 100 students or more and in courses where mathematics plays an important role this is not a solution due to the enormous amount of work to grade the assignments or because of the learning goals of the course.

Therefore, it was decided to opt for online proctored exams in cases where other solutions are impossible. Online proctoring is not only a sensitive issue because of privacy regulations, but the university also lacked any experience on a larger scale. Within a short time a company was found that offered online proctoring facilities which satisfied our privacy regulations [5]. Apart from that guidelines were agreed upon with the students in the university council that met most of the objections against online proctoring. For example, a student can choose for an opt-out and is offered an alternative exam on campus in that case. As

a result, protests against online proctoring, which happened in several other universities in the country, did not happen in Eindhoven.

Online proctoring means that the webcam is switched on and all images are recorded and stored. Moreover, all activities on the computer are monitored and, depending on the settings of the exam, some things are not allowed, for example using a web browser for other websites than the exam. Deviations from normal behavior are noticed statistically and can later be studied in detail by watching the recorded images. A team of people was available to perform this task. In addition, at the start of the exam the student has to prove his or her identity, a room scan is made by means of the webcam and the students have to show the contents of their table to verify that there are only permitted items. The permitted items depend on the exam and are determined by the responsible teacher of the course, for example a calculator, a book, empty sheets of paper, etc.

Nevertheless, some problems occurred during the exams, in particular in cases where students had to upload files with their solutions, and some exams suffered from technical problems due to very large numbers of students. In two or three cases an additional exam was scheduled a few weeks later.

The course Heat and Flow could profit from experience obtained in other courses, since it only starts after these first exams in corona time, end of April.

It certainly was an advantage that we had a complete online version of the course that had already been tested in the previous year. However, we decided that this online version is not sufficient, since there is also a group of students with a different learning style, who benefit much more from synchronous learning. Therefore, apart from the online version we also scheduled lectures, instruction sessions and guided self-study sessions in the usual way. Apart from that the students could view the recorded lectures of the previous year, but they were in Dutch while from 2020 onwards also a number of international students follow the course.

The online lectures were given from home in MS Teams. Students could ask questions

through the chat function, or at the end of each lecture by opening their microphone. The capacity of MS Teams is 300, which is less than the number of registered students, but this did not present a problem, since a large number of students does not follow the lectures live. The lack of a blackboard necessitated to explain almost everything by using slides, which is a far less effective way to explain longer derivations and examples. In order to increase the interaction during lectures, we used to ask multiple-choice questions, to which students answer by raising their hand. We replaced this by mentimeter questions (see figure 4) [6], which proved to be an even more effective way of interaction.

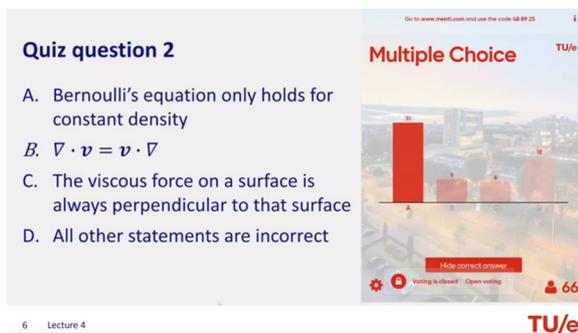


Fig. 4: Example of a mentimeter question used during the live online lectures.

The number of students that attended the lectures decreased in time, as usually, starting with almost 200 in the first lecture and dropping to approximately 100 in the last lecture. The lectures were recorded and made available to the students in a private channel in YouTube. The number of views ranged between 100 and 200, but the average view has a duration much shorter than the duration of the lecture.

For the instruction sessions I bought a whiteboard, which enabled me to explain the exercises in a better way than by using slides. However, the webcam does not focus on the reflecting surface of the whiteboard and I needed to use one of my hands to focus the webcam on the right spot (see figure 5). The size of the whiteboard is much smaller than the size of a blackboard in the lecture room, which also has consequences for the way to explain exercises. MS Teams has the functionality to show the image from my webcam full

screen, but this is not the case in the recordings. Fortunately, at the time of the course, the number of screens shown in the recordings was limited to four, so that the text was still well readable.

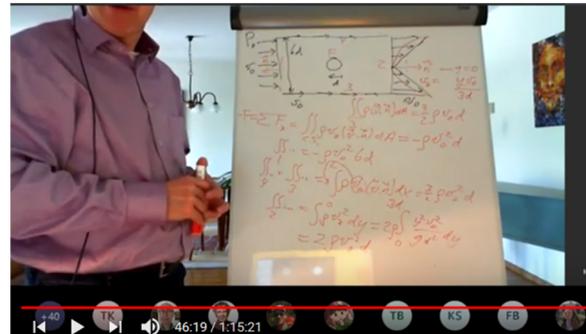


Fig. 5: Whiteboard used during instruction sessions. The figure shows a recording of the MS Teams session of the instruction. See also <https://youtu.be/59BLi94VFms>

The biggest problem was the GSS. We organized this also in MS Teams and usually 6 persons were available to answer questions. However, the number of questions was so low, that most of the teacher assistants were hardly occupied. Furthermore, at that time we did not yet have good solutions for writing or drawing on a whiteboard.

The exam of the course was scheduled on July 1, when the campus was just in the process of starting up laboratory activities for PhD and MSc students and staff was allowed to work in the office for one day a week. All other activities, including meetings and exams, were still online. For the exam of a course like this, the only option was an online proctored exam.

Based on experience of the exams of the previous quarter, we decided not to use the upload function, but organize the questions in such a way that the answer could be given digitally. As in the previous years, the exam had two types of questions. Half of the time was spent on multiple-choice and numerical questions in which only the answer should be given. In the system we used, Ans Delft [7], these questions are automatically graded. The remainder of the exam consisted of two larger exercises with multiple questions. The equations that need to be typed could be given symbolically, for example alpha for the Greek letter α and $\text{int}(f(x),0,1)$ for $\int_0^1 f(x)dx$. Students could

test the system and this way of writing equations in the week before the exam was held.

The exam differed in two other aspects from earlier years. In view of a necessary sanitary break, the exam was split in two parts of 90 minutes each with a fifteen minutes break in between. Also, we allowed the use of the book, or other material on paper, while normally we only provide a list of the most relevant formulas. The reason for this change was to reduce the possibilities for cheating. A drawback is that open-book exams are usually more difficult, since the examples from the book cannot be used. Only one student made use of the opt-out and made the same exam on paper on campus. His results were uploaded in Ans Delft to be graded in the same way as the results of the other students.

The use of digital assessment has large benefits in the process after the exam. First of all, instead of a huge pile of paper of all individual exams, which requires a few hours to sort everything out and make sure that no exam has been lost, all results are available directly after the exam and ordered per student and question. Multiple-choice and numerical questions are automatically graded and for other questions grading criteria can be set, which is a good guarantee for consistent grading and accelerates the grading process. Also, it is possible to perform the grading by multiple persons at the same time.

After the grading has been finished, students can inspect their exam during a fixed period of time and see which errors they have made and how their grade is determined. If they have any questions about the grading, they can ask them in the same system and the person who graded that exercise receives a notification. We noticed that the number of students who used the opportunity to inspect their exam is way bigger than in case of a paper exam.

After the exam, students complained that the division of the questions over the two parts was not good. The multiple-choice questions required far less time than the open questions. Therefore, in the resit we split the questions according to the topic: part 1 about flow and part 2 about heat, while both parts had multiple-choice questions and one open exercise.

During the exam no technical problems happened, although a few students were automatically expelled since they tried to do something that was not allowed. After the exam no deviations from normal behavior were detected.

The results of the exam were not as good as the year before, but clearly better than in previous years. The success rate of all students who made a serious attempt during the exam was 61%, while the distribution of the grades was comparable to the year before (see figure 6). A better distribution of the exercises over the two parts of the exam would probably have resulted in a higher success rate. Moreover, the very limited attendance of the GSS, which is the best preparation for the exam, will certainly have influenced the results and is an important point for improvement in the future.

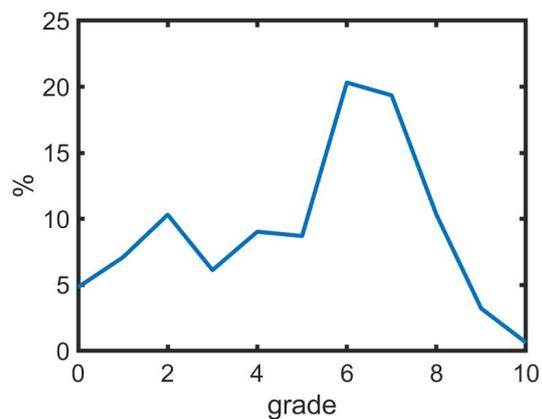


Fig. 6: Distribution of grades of the first exam of Heat and Flow in 2020. A minimum grade of 6 is required to pass the course.

The evaluation of the course, which is always performed directly after the exam in digital format, revealed that the students would have appreciated a study guide to choose their way into the available course material. There is so much material available, that they need a guide that provides different ways to study the topic. We took this into account in the set-up of the next academic year. Moreover, there were some complaints about the exam, in particular about the way to type equations and the time required to finish the exam.

In one of the lectures I also used mentimeter to ask questions about the set-up of the course and the exam. On a scale of 1-5 the question

“Are you satisfied with this way of teaching” scored 4, which is satisfactory given the circumstances. On the question about the exams, 96% of the students indicated that they prefer an online proctored exam at the normal scheduled day over an on-campus exam postponed until November.

4. Academic year 2020-2021

At the start of academic year 2020-2021, the corona situation had improved so much, that students were again allowed to have education on campus, but only in smaller groups and keeping a distance of at least 1.5 m. Especially experimental work, construction and testing were allowed in small groups, but it was also possible to organize GSS sessions for small groups. For every lecture room a maximum number of students was determined, which usually is about one fifth of the normal capacity. At that time on-campus lectures were not allowed, since this was considered an inefficient way of knowledge transfer.

This situation of relaxed corona measures did not last long, however. By December the number of infections and hospitalizations increased so much that all on-campus teaching apart from a few practical trainings was forbidden again. However, on-campus exams were possible in most cases with an exception for the largest courses for which no suitable space was available.

During this time, experiments were conducted to find ways to organize online GSS sessions in such a way that student participation increases. The department bought a number of writing tablets for the teacher assistants in order to facilitate explaining the exercises, writing formulas and drawing pictures. Experience from the first-year course calculus, which is taught to approximately 2000 students, indicated that student engagement increased by working in small groups with a personal tutor, who has a more direct and personal interaction with the students in his or her group(s).

At the time Heat and Flow started, end of April 2021, small-scale on-campus teaching was possible again and we decided to teach the lectures and give the instruction sessions in a lec-

ture room for a very limited number of students, while the others can follow this through a livestream. The livestreamed sessions are also stored and can be watched any time later.

As in the year before, the students that are not present can use the chat function in MS Teams for questions, and questions in mentimeter are used for increased interaction. Although the number of students that attend the lectures is small, those who do are very satisfied with the increased possibilities for interaction and benefit from the lesser opportunities for distraction in the lecture room than at home. One issue the teacher of a combination of on-campus presence and livestream has to deal with is that the livestream has a delay time of 20 seconds. This is necessary to put the video stream in the correct high-quality format. This delay has to be taken into account especially in the mentimeter questions. Also, direct interaction with the students that follow the livestream by speech is not possible, in contrast to the MS Teams lectures of the year before.

Since on-campus lectures are still not allowed, we chose for the format of so-called studio classroom, which is a mixture of lecture, instruction and small exercises made by the students. Students who want to be present have to register for every session they want to attend in our learning management system. In the four-hour session once a week there is only space for 20 students, while in the two-hour session 50 students are permitted. Experience in the first part of this academic year has taught us that students prefer to be on campus for a longer duration. For a sessions of two hours the travel time is sometimes longer than the time actually spent on campus. That is the reason why most on-campus sessions are in blocks of four hours.

The online guided self-study is organized in the following way. Students can choose between two ways of participation. They can either register for participation in a small group of five students with a personal tutor, or they can participate in one large group. In the first option they are expected to attend almost every time. Every session the tutor explains one of the exercises in detail and stimulates the students to

work together on the other exercises. In order to facilitate this, we hired 13 teacher assistants, each of which is responsible for one or two groups. The tutors followed a short course to learn methods to increase student engagement. For our course 25% of the students indicated that they want to participate in a small group and a similar percentage had a preference for the large group. The number of questions in this large group is very small. Most students in the large group work individually and are able to solve the exercises with the help of the online material.

Of course, the number of teacher assistants is significantly higher than in other years. The university provided the necessary money to facilitate this way of teaching as one of the measures to cope with the consequences of the corona pandemic.

At the moment of writing we are halfway of the course and the attendance of the online GSS is still rather good. Students who registered for participation in a small group, tend to be there almost every week and they work until the end of the session, which is at 17:15 on Friday afternoon.

Fortunately, the exam can and will be held on campus. Only for students who cannot attend the exam on campus because of corona reasons, an online proctored exam will be organized. This exam is the same as for the other students and will be held at the same time. The exam is no longer split into two parts. Students are allowed to have a sanitary break during the exam. Valid reasons for this type of exam are medical complaints that could be related to corona, belonging to a high-risk group, or being in quarantine. International students who chose to return to their home country do not get the possibility of an online exam, since students are expected to be able to come to the campus for several educational activities, including exams.

The benefits of the digital assessment in Ans Delft made us decide to use the same system for the on-campus exams. The exams are not directly taken in digital form, since this would make the use of equations more difficult. Instead the exams are printed, leaving sufficient space for the answers after every question. Af-

ter the exam, all papers are scanned and uploaded in Ans Delft. Multiple-choice questions are still automatically graded and for all other types of questions grading criteria can be applied. The benefits of synchronous grading by multiple persons and digital inspection of the exam by the students remain. Also, the administrative process is greatly reduced, since the system knows where the answers to all questions are and it is possible to grade all answers to a question in consecutive order. Only in case a student needs more space to answer than anticipated by the teacher, the person that does the grading has to search for the answer.

5. Conclusions

Over the past years the course Heat and Flow has been adapted in several ways with the objective to increase the success rate, but without changing the learning goals and the level of the exam. Taking into account different learning styles of students, the possibility has been created to learn the course material in different ways. Students who prefer to learn individually at the time they want, can now make use of an online version of the course, which consists of a set of short texts and small video lectures, a number of step-by-step recorded solutions to selected example exercises and a set of online exercises with automatic feedback on wrong answers. Students who prefer attending lectures and instruction and exercise sessions can still do so.

In order to ensure that students starts learning well before the exam, a method of digital progress tests has been developed. During the quarter in which the course is taught, students have to make a number of these progress tests with sufficient result to obtain the final grade for the course. The number of attempts of the progress tests is unlimited, but within a restricted time. This system together with the use of the online version of the course resulted in a significant increase in success rate and has since been transferred to a number of other courses within the department.

In 2020 the corona pandemic resulted in a lockdown in which on-campus teaching was not permitted. Still, the dual way of learning, both synchronous and asynchronous, was

maintained by giving the lectures and instruction sessions fully online in MS Teams. Written exams were replaced by online proctored exams. Although the success rate was lower than in the year before, it was still significantly higher than before the progress tests were introduced.

Apart from the progress tests as a method to encourage the students to learn in time, the way to best organize sessions in which the students practice exercises is a lesson learned during the corona pandemic. The most important element of these sessions is the possibility to obtain feedback, next to the possibility to work together on the exercises in small groups of students. The method to organize these exercise sessions in very small groups of around five students, each with a personal tutor, appeared to work well, at least for the students who have the need to work in this way. The tutor plays an important role in stimulating the group to work together and in starting each meeting by explaining one of the exercises. This method is, however, not very cost effective, as many tutors are needed for big courses. The costs can be reduced by allocating one tutor to two groups. Moreover, by letting the students choose between participation in a small group or not before the course starts, less tutors will be required.

The department noticed that in the time of the pandemic the study success of the students in general did not deviate from other years. Although at first sight remarkable, this can be explained from the fact that studying is one of the few things that are still possible. Many other activities in which students normally participate have been cancelled, for instance group sports, events organized by student and study associations and part-time jobs in pubs and restaurants. Also less time is spent in traveling to and from university, since (almost) all teaching activities can be followed from home. Average grades and pass rates of courses are very similar to other years and the percentage of first-year students that fulfil the requirements to enter the second year is also unchanged.

This does not mean, however, that students do not suffer from the corona pandemic. Apart from corona infections, which usually only

have mild consequences at the typical age of a student, many students suffer from loneliness and lack of perspective. Especially the group of international students who entered in September 2020 did not have any serious opportunity to get settled and make sufficient contacts with other students. Several of them moved back to their country of origin, which could have serious consequences for their study, since in several occasions attendance of teaching activities on campus is obligatory, in particular in practical trainings and written exams. But also other students experience psychological problems. Academic advisors, who can refer students to student psychologists in cases of problems, report that they get many more requests for advice from students than in other years.

A survey among first-year students in Mechanical Engineering revealed that almost 2/3 of them feel lonely sometimes or often. More than 50% indicated that the workload of the program is too heavy because of online studying and loneliness, although almost all of them would still have chosen the same study.

Finally, online proctoring is a useful method to organize written exams, if good care is taken of privacy rules of students. To this end, students should be well consulted and taken along in the process of setting up online proctoring. Also, it is very important to give students the opportunity to practice with this method of exams. In case students need to make drawings or write a large number of mathematical equations, an online proctored exam is only possible, provided that students can scan and upload their written papers. Uploading often leads to problems, especially in exams with a large number of students. Problems can be avoided by organizing on-campus exams in a safe way for almost all students. In that case, only those who have corona-related complaints need to make use of the online proctored exam.

A lesson learned during the corona pandemic related to exams is that an online exam system has large benefits in the process of grading and inspection of the exam by the students after grading. Not only a lot of time can be gained because of reduced administration, but also consistent grading is easily facilitated.

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