

FLIPPED CLASSROOM IN TEACHER EDUCATION

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The lecture Basic Principles in Physics is a compulsory subject in the education of primary school teachers at TU Dortmund University and actively attended by 100 to 150 students. Previously the lecture was held as a classic lecture utilizing mainly power point slides and experimental demonstrations. For the winter term 23/24 the lecture format was shifted towards a more interactive format, aiming at specific physics problems to be solved as part of the lecture. In order to free up the necessary time in the lecture itself, the conveyance of knowledge was shifted to the students' preparation for the individual lectures, by providing texts and videos, which were aided by a short quiz. The lectures as well as the preparation were accessed over the entire semester. This paper provides an overview over the results obtained from the assessments and the final exams, as well as the lessons learned.

Keywords: Flipped Classroom, Just-in-Time-Teaching, Teacher Education

INTRODUCTION

The lecture Basic Principles in Physics is a compulsory subject in the education of primary school teachers at TU Dortmund University [1] and is actively attended by 100 to 150 students in their third semester. Providing students with fundamental knowledge on physics, which can be applied in their own teaching throughout the course of their professional career, is one of the main goals of the lecture. Within the curriculum, the lecture is embedded in the general science education of the students, which also contains lectures with similar aims in Biology, Chemistry and Engineering [2]. The lecture is taught as a weekly 90 minute lecture over the course of one semester. In order to proceed with their education students are required to pass a combined exam on Physics and Engineering at the end of the semester. Although the exam covers two subjects, topics from both subjects are clearly separated. Students pass the exam in case they obtain at least 50% of the total points, regardless of the subject the points were obtained in.

The lecture covers a broad range in classical physics, including Newtonian mechanics, thermodynamics, electricity and magnetism as well as some aspects of astronomy, for example the solar system.

Over the last years, the lecture was taught in the form of a classical lecture, utilizing mainly power point slides, experimental demonstrations and blackboard calculations. Within this lecture format the engagement of the students was relatively low, which was reflected in the lecture assessments and the relatively poor performances in the final exam. For the winter term 23/24 the lecture format was re-designed to allow for more student participation and the focus on specific physics problems to be solved as part of the lecture. Flipped classroom (cf. [3,4]) and just in time teaching elements [5] played a major role in the re-design. In order to assess the students perception and engagement the lecture was closely monitored via regular assessments throughout the entire semester. Due to the overall structure of the lecture, it was found to be very difficult to assign extra credit to students for participating in the assessments. It would, however, been beneficial to do so in order to increase the overall participation rate.

This paper will provide an overview over the results of the assessments and some selected learning outcomes, reflected by the final exam, and is organized as follows: The next section will first provide an overview over the interest and existing knowledge of the student group and briefly explain the key elements of the re-designed lecture format. After that, the outcomes of the assessments as well as an analysis of selected topics from the final exam will be presented. The final section will conclude the paper with lessons learned and provide an outlook on possible further improvements for the lecture.

CHARACTERIZATION OF THE STUDENT GROUP AND RE-DESIGN OF THE LECTURE FORMAT

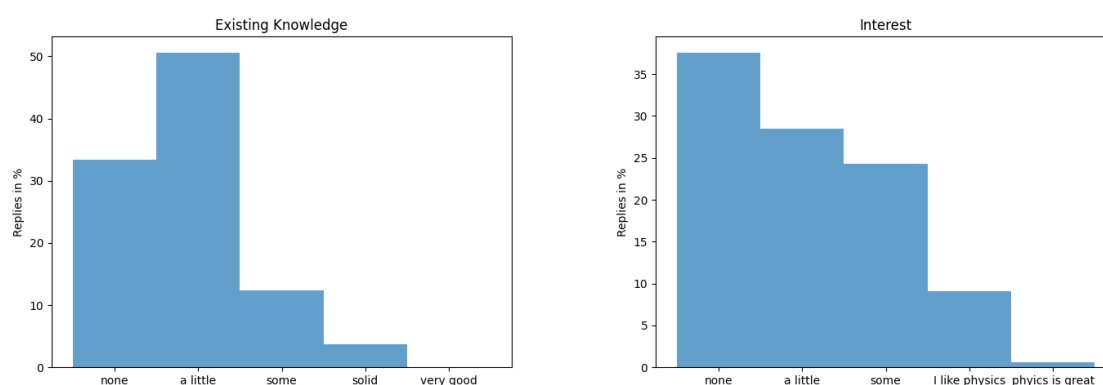


Fig. 1. Existing knowledge (left) and general interest in physics (right).

As a central part of the first lecture the students were asked to participate in an assessment aiming at analyzing their existing knowledge, as well as their general interest in physics. This particular assessment was carried out in class via an audience response tool (mentimeter) The outcome of the assessment with respect to the existing knowledge in physics is shown in Fig.1 (left), whereas the outcome with respect to the students' interest is shown on the right hand side of Fig.1.

One finds that majority of the students claims that they have either none or only a little physics knowledge. Only 12% of the students indicated that they have some knowledge in physics and (expectedly) even less (4%) claim that they possess a solid physics knowledge. None of the students responded that they had a very good knowledge in physics.

The situation is similar for the students' general interest in physics, where the vast majority of the students claims that they have either no (38%) or only a little (29%) interest. Almost a quarter (24%) of the students responded that they had some interest in physics, whereas less than 10% stated that they liked physics. A single of the 165 participating students responded that physics was great.

In addition to the two items discussed above, the students were also asked for how many years they had learned physics in school, if they participating in the lecture for the first time and if they had any experience with the flipped classroom method.

Taking into account the outcome of these assessments, one can conclude that the majority of the learning group has neither a strong interest, nor a solid knowledge in physics. This indicates that a strong activation of the students should be built up during the lecture in order to keep the students engaged, which was also expected to result in an improved learning outcome. In addition to providing specific physics problems (preferably from the everyday

experience of primary school children) an increased engagement of the students, was one of the primary goals of the re-design of the lecture, which will be described in the following.

For the winter term 23/24 the lecture format was re-designed using central elements from the flipped classroom method and just in time teaching. The overall structure of the lecture consisted of three central parts: the students' preparation for the lecture, the lecture itself and additional exercises provided to the students on central topics.

The preparation of the students was organized via the online learning environment moodle [6] and presented in individual units. Each unit started with a brief general introduction on the topic, listing the main points to be prepared by the students. Although it was generally left open, which materials the students should utilize during the preparation phase, texts and videos on the individual topics were provided. From the student side, the preparation was concluded by participating in a short quiz, covering selected matters from the texts and videos.

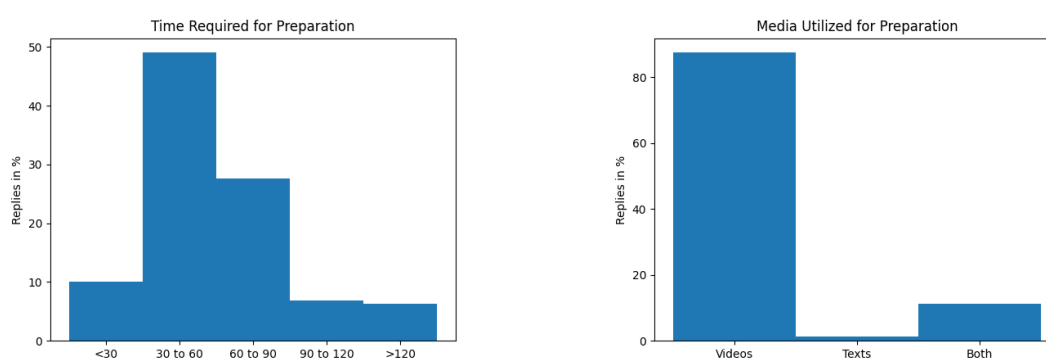


Fig.2. Time Demand (left) for Preparation and Utilized Media (right).

Before the lecture, the students were offered to participate in a short assessment offered via moodle, where they could indicate how much time they had spent on the preparation material in total and which of the provided materials they actually utilized in their learning. Furthermore, the students were given the opportunity to write down certain topics they had not or not completely understood during the preparation.

Both, timing and not fully understood topics, were considered critical point for the overall success of the new lecture format. In case students are overwhelmed by too much learning material to be covered before the actual lecture, they might become disengaged and ultimately refuse to prepare for the lecture. In order to prevent this, the goal was that on average students would spend 30 to 60 minutes per week on the preparation for the lecture.

With respect to not fully or not all understood topics, these topics were extracted from the assessment and separately addressed during the lecture. Unfortunately it is in many cases infeasible to address all of the mentioned topics. However, picking the three to four most frequently mentioned ones, was expected to improve the overall learning outcome of the students.

Fig.2. depicts the time demand (left), as well as the media utilized for lecture preparation by the students. One finds that the average goal of having the students spend 30 to 60 minutes on the preparation was met to a large extent. It should, however, be noted that the figure depicts the students answers aggregated over the entire term. Due to the different complexity of the individual topics, the time required for preparation slightly varied from topic to topic. The

continuous monitoring of the students' efforts, however, allowed for longer preparation assignments to be followed by shorter ones, to even out the time demand over the course of the semester.

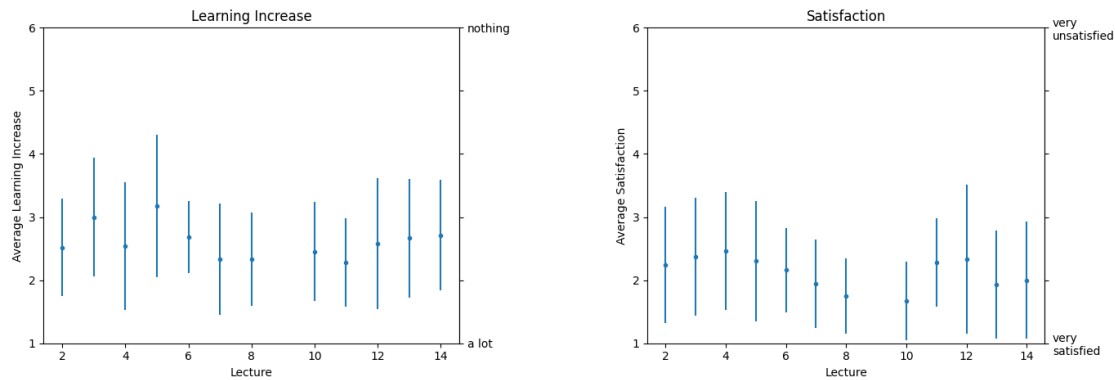


Fig.3. Average learning increase (left) and average satisfaction (right).

With respect to the utilized media it is not surprising that the vast majority of the students (88%) solely relied on the videos for preparation. Approximately 11% utilized texts and videos to prepare for the lectures, whereas less than 2% of the students used the texts.

Within the lecture the students were confronted with specific physics problems, that could be solved using knowledge acquired in the preparation phase. For low complexity problems of the students were either asked to answer via an audience response tool. In order to solve more complex problems possible solution strategies were discussed in class and the problem was then solved on the blackboard in a collaborative effort.

RESULTS OF THE LECTURE ASSESSMENT

Assessing the students perception of the lecture over the entire course of the semester (also via moodle), allowed for a continuous monitoring of the latter. The outcome of said assessment with respect to the students' satisfaction with the lecture format and their perceived learning increase is shown in Fig.3. While the students' perceived learning increase is shown on the left hand side of the figure, the students' satisfaction is depicted on the right hand side. For both subfigures, one finds that the first, the last and the ninth lecture were not evaluated. For the first lecture, this is due to the fact that this lecture was utilized to explain the motivation behind the chosen lecture format to the students and to clearly communicate the expectations with respect to preparation. The last lecture, was labelled irrelevant with respect to the exam on short notice, due to a strike of the German train personnel, which hindered a large amount of students from personally attending the lecture. Lecture number nine was held by a substitute in a classic lecture style and was therefore also not evaluated with respect to the students' perception on the changed lecture format.

For the assessment of the perceived learning increase, the students were provided with a scale from one to six, with one indicating that the students learned a lot, and six indicating that the students did not learn anything. To obtain the average learning increase for the entire learning group, the students' replies were averaged and the depicted error bars indicate one standard deviation. One finds that for all lectures the average perceived learning increase is between two and three, indicating that the participating students were able to increase their knowledge by a substantial amount, by participating in the lecture.

For the assessment of the students' satisfaction, the learners were again provided with a scale from one to six. This time one indicates that the participants were very satisfied with the lecture format, whereas six indicates that the learners were not satisfied at all. The participants' satisfaction was again analyzed by averaging the students' answers. As above, the depicted error bars correspond to the one sigma environment. The students' average satisfaction with the lecture format is found to be in the range between two and three for all lectures, indicating that the learners were relatively satisfied with new format. However, the error bars indicate that some students were more satisfied with the lecture format than others.

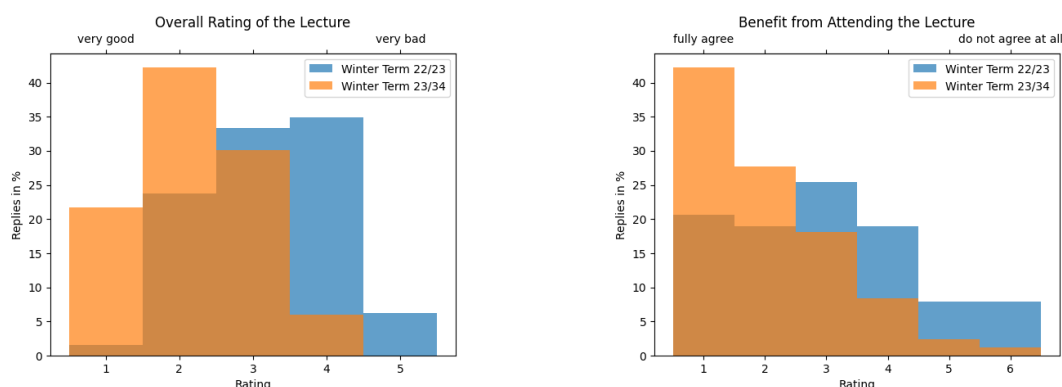


Fig. 4. Overall rating of the lecture (left) and perceived benefit from attending the lecture (right).

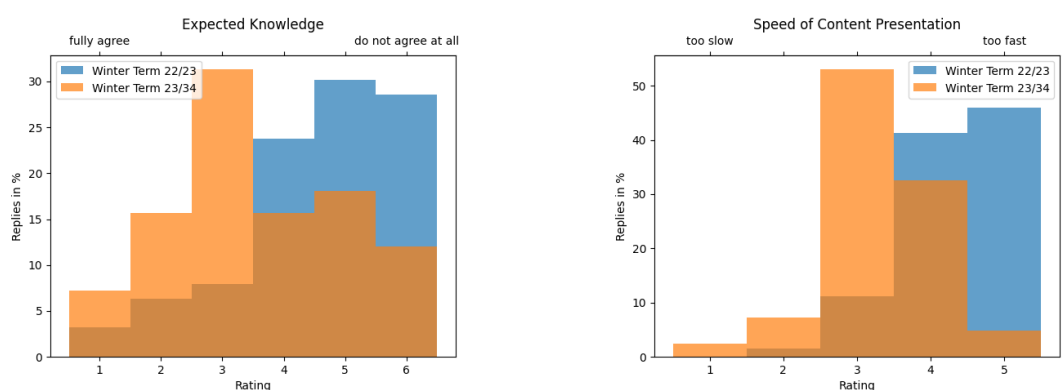


Fig. 5. Expected knowledge (left) and speed of the presentation (right).

RESULTS OF THE FORMAL LECTURE EVALUATION

The lecture was also formally evaluated via a different online survey tool by the physics department via a standardized set of questions. This formal evaluation is carried out on all classes exceeding a certain number of participants after approximately 50% of the lectures have been held. The evaluation is quite detailed and this paper will only present four key findings with respect to new lecture format.

Figure 4 shows the overall rating of the lecture (left), as well as the students' perceived benefit in attending the lecture compared to studying the material by themselves. The results for winter term 23/24 (orange) are compared to the results for winter term 22/23 (blue), where the lecture was held as a classical lecture.

With respect to the overall rating of the lecture one observes an increase towards a better rating. In WT 23/24 approximately 64% of the students rated the lecture as good or very good, compared to 25% in WT 22/23. For WT 23/24 none of the participating students rated the

lecture as very bad, compared to 6% for WT 22/23. Considering the perceived benefit from attending the lecture in WT 23/24, 70% of the students agree or fully agree that they benefit from attending the lecture, compared to 40% in WT 22/23. In WT 23/24 only a very small portion of the students (4%) do not (or only marginally) agree that they benefit from attending the lecture, compared to 15% in WT 22/23.

The left hand side of Fig. 5, depicts the answers to the question, whether the students did possess the knowledge expected for actively following the content of the lecture. Results for WT 23/24 are shown in orange, whereas the results for WT 22/23 are depicted in blue. Although, a large number of students (46%) is under the impression that they do not possess the expected knowledge, one observes a shift to the left. This shift indicates that for WT 23/24 more students had the impression to possess the required knowledge. This becomes even more interesting, when considering that the knowledge required for the lecture remained unchanged with respect to WT 23/24. One can therefore conclude that the students' perception of their already existing knowledge was positively influenced by the learning material provided for preparation.

The right hand side of Fig. 5. shows the speed of the content presentation as perceived by the students. Results from WT 22/23 are shown in blue, whereas results from WT 23/24 are depicted in orange. A numerical rating scheme ranging from one to five was used, with one indicating that the content was presented too slow and five indicating that the content was presented too fast. For WT 23/24 the graphic clearly shows that the majority of the students (53%) responded with three, which implies that the speed of the presentations was just about right. This can be considered a big improvement to the overall quality of the lecture, compared to WT 22/23 where 87% of the students perceived the speed as either too fast or slightly too fast.

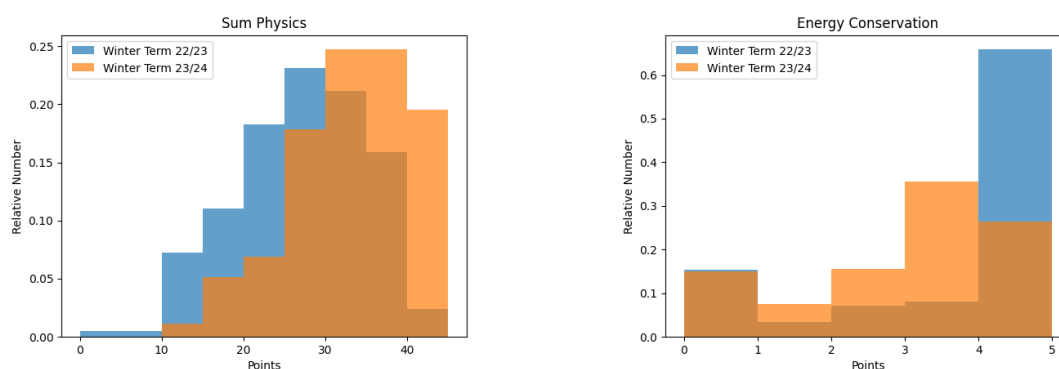


Fig. 6. Number of points obtained by the students in the final exam (left) and number of points obtained by the students in a question on energy conservation (right).

RESULTS OF THE LEARNING OUTCOME

The students learning outcome was assessed via the results of the final exam. Within those final exams questions were exemplarily selected based on the underlying skills, required for solution. These questions were then compared to questions from the previous exam, which tested for similar skills. As part of this paper, the results with respect to the concepts of energy- and momentum conservation, as well as in one question aiming at the simple reproduction of knowledge (e.g. asking for different kinds of temperature scales or different conservation laws),

will be presented. Furthermore, the overall number of points obtained by the students will be compared to the previous exam.

Due to the curriculum taught at TU Dortmund University, the exam is a single exam taken simultaneously on physics and engineering. The duration of the exam is 90 minutes, with a total number of points of 90. Students pass the exam in case they receive at least 50% of the total points independent of the subject they received them in. It is only possible to pass or fail the exam as a whole. For this paper, the results of the exam are only evaluated with respect to the physics questions.

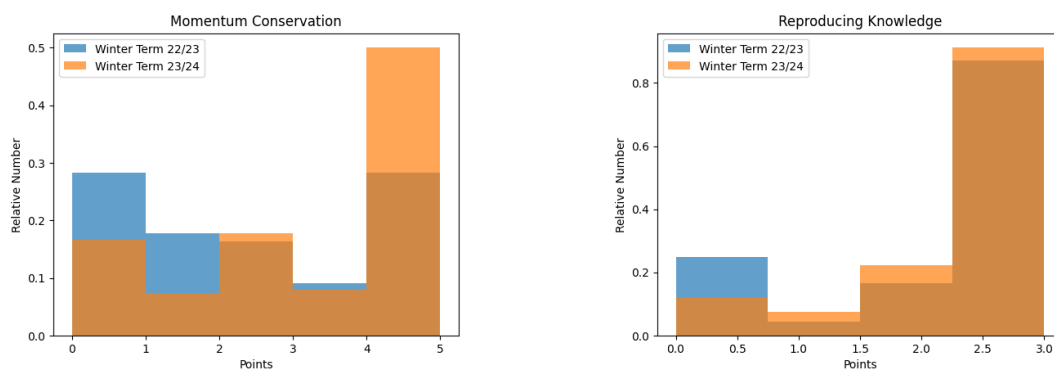


Fig. 7. Number of points obtained by the students in a question on momentum conservation (left) and in a question requiring the simple reproduction of knowledge (right).

Figure 6 shows the total number of points obtained by the students in the final exam (left), as well as the number of point obtained in a question on energy conservation (right). Results obtained for WT 22/23 are shown in blue and results obtained for WT 23/24 are depicted in orange. With respect to the total number of points one recognizes a prominent shift towards a larger number of points, when comparing WT 23/24 and WT 22/23. Comparing WT 22/23 and WT 23/24 with respect to students ability to apply the concept of energy conservation, one finds that in 23/24 a smaller number of students received the maximum number of points on this question.

Figure 7 shows the number of points obtained in a question on momentum conservation (left) and in a question that required the simple reproduction of knowledge (right). With respect to momentum conservation one finds that in 23/24 (orange) approximately 50% of the participants obtained the maximum number of points on this question. This is an increase compared to 22/23, where approximately 30% of the students obtained the maximum number of points. One further observes an overall shift in the distribution towards a larger number of points, when comparing 22/23 and 23/24. With respect to the reproduction of knowledge one also observes a shift towards a larger number of points, when comparing WT 23/24 and WT 22/23. Although in this case, the shift is less prominent one finds that a smaller number of participants (approximately 12%) obtained no points on this question in 23/24 compared to approximately 25% in 22/23.

SUMMARY AND OUTLOOK

For the winter term 23/24 a lecture that was previously taught in a classical docent-centered setting was changed towards a more student-centered approach, which adopted elements from just-in-time-teaching and the flipped classroom method. In addition to the mandatory evaluation of the lecture and the results of the final exam, which provided insights into a change

in performance, the students' perception of the lecture format was continuously monitored over the course of the semester.

The analysis of the regular assessments revealed that the students were generally satisfied with the chosen lecture format and that they perceived a relatively high increase in learning when actively attending the lecture.

With respect to the formal lecture evaluation it was found that the overall rating of the lecture was improved and that the students perceived attending the lecture as more beneficial. Furthermore, the overall speed of the lecture was rated as just about right, which is a direct consequence of providing students with preparatory material. Having the students work through said material before class, frees up additional time within the lecture, which can e.g. be put to use by providing additional examples or by covering certain aspects in greater depths.

Considering the results of the final exam, it was found that the students performance greatly increased compared to winter term 22/23, as a prominent shift in the distribution towards a larger number of points is observed. Although a slight decrease in the total number of points is observed for a question on the conservation of energy, the students' performance on a momentum conservation task was found to greatly improve. For a question that only required the simple reproduction of knowledge, this enhancement in the students' performance is also apparent but less prominent.

In summary, changing the lecture format from a traditional format to flipped classroom teaching can be considered very successful. The improvements not only manifest themselves in the students' performance in the final exams, but also in their more positive attitude towards the lecture in general. The very promising results and the very positive feedback by the students are very motivating with respect to a permanent change in the lecture format.

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