

Balancing Student Workload with Learning Outcome – The Search for Suitable Assignment Format for a Fluid Mechanics Lab*

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In this paper, the authors describe different revisions to a fluid mechanics module at the University of Iceland where they aimed to find a suitable assignment format for the laboratory component. Traditionally, a full laboratory report is expected from every laboratory session. Students in the course, however, claimed that the laboratory component of the course was too time consuming and their learning from it was minimal. Therefore, attempts were made to design an assignment that would reduce student workload without decreasing their learning. The study covers five years of course revisions. In the first two years, students were required to submit a full report for each experiment, but in the following three years, students submitted a worksheet, short report or Excel sheet assignment. Students' perceptions of each assignment format were assessed using the university midterm and end-of-term teaching evaluation surveys along with a laboratory-focused survey. In addition, a focus group interview with a group of students was conducted in the last year. The results indicate that alternative assignment formats outperform the full report in students' report of workload, learning gains and satisfaction with the laboratory component.

Keywords: laboratory teaching; mechanical engineering education; chemical engineering education; workload; assessment; assignment format

1. Introduction

In this paper, the authors seek a suitable assignment format for the laboratory component of an undergraduate fluid mechanics (FM) course in mechanical engineering (ME) and chemical engineering (ChE) study programs at the University of Iceland (UoI). To improve the laboratory course, curriculum changes were made regarding the structure (described in detail in a paper in preparation by the same authors as this paper [1]) and assessment of the course. This paper focusses on the development of assessment practices. The students participating in the course are students in their third year of a three-year BSc degree in ME, in their second year in ChE or at various levels from different majors, mostly engineering physics. The goal is to address the issues raised by former students that the laboratory component of the course is extremely time consuming and provides limited help in grasping the main concepts of the course. The aim of the laboratory component is to give hands-on experience on various aspects of FM to provide students with a deeper understanding of the subject. Evalu-

ating the benefits of different assignment formats that meet this aim within a reasonable workload is the goal of this paper.

The research question for this study can be formalized as:

- What is the most appropriate type of assignment for each experiment with respect to student workload and learning in the FM course?

A short review of the literature relevant to this study is presented in the following section. Thereafter, a description of the variation in assignments is given. The results are based on the university-wide midterm and end of term student evaluations (2014–2018), a survey focused on the laboratory (2015–2018) and on an analysis of a student focus group on the laboratory component (2018).

2. Literature Review

2.1 Assignment Format

Assignments in laboratory sections of courses are most commonly full reports for each experiment (e.g., [2–4]). However, it is not given that this is the

assignment format from which students learn most. In order to determine that, one needs to be clear on the learning outcomes of the given course [5]. There is common agreement that students graduating with a BSc in ME or ChE need to know how to write high quality reports. However, that is a common learning outcome of entire study programs and improving report writing might be beyond the scope of individual courses. Report writing needs to be covered in some, and probably more than one, courses in the study program and FM may or may not be one of those courses.

In some universities, the curriculum organization is such that the laboratory sessions are all concentrated in a course that covers the subjects of the entire study line. In such courses, it is expected that report writing is a large part of the learning outcome of the course, and it is natural that a full report on each experiment is required. However, when the curriculum organization is such that all laboratory sessions are included in each course on the subject, report writing does not need to be addressed in all those courses. In the courses where report writing is not a part of the learning outcomes, other assignment formats may be more suitable in the laboratory sessions. The question of whether improving report writing is part of the learning outcomes in FM is one that the authors of this paper answered negatively. Rather a more appropriate learning outcome related to the laboratory section of FM is that students passing the course should be able to:

- Conduct experiments and measurements on pressure, velocity and forces in relation to classical problems in fluid mechanics.
- Analyze their own experiments and explain the results using the theory.

The educational aim of the laboratory section is to develop both experimental skills and deepen student understanding of theory. Bearing these learning outcomes in mind, the focus is on what assignment format is best aligned with them. Other report formats suggested in the literature include returning single sections of lab reports [6], homework [7] or assignments [8] based on experiments, blogging [9], real time visual comparison of students' results and results from other students [10], quizzes, oral presentations [11], synopsis reports [12] and portfolios [13]. Grant [11] uses a mixture of oral and written reports to assess students' laboratory performance. The oral presentation is immediately after the laboratory, with one-on-one assessment and immediate feedback. Heslop [6] tests the effects of, among other things, letting students return one section of a report after each session, receiving detailed feedback and then

returning one report at the end of the last experiment in the laboratory section. This increased students' satisfaction, reduced grading time and is in accordance with Bloom's taxonomy [14] of building on previous levels of knowledge and developmental skills.

Chen, DeMara, Salehi & Hartshorne [13] split the laboratory into two cohorts. Both cohorts wrote a weekly free-form narrative portfolio and a monthly technical report during the section. Grades given for the portfolio were complete, incomplete and no submission. The difference between the two cohorts was that one cohort wrote biweekly lab reports and received feedback a week later. The other cohort did a biweekly in-lab test online on the previous week's laboratory with immediate feedback. The cohort writing the lab reports had less learning and lower satisfaction with the laboratory and the teaching assistants serving that cohort spent more time on grading and less time attending to the specific needs of students. Hoffa & Freeman [12] tested the effect of using a synopsis report instead of a traditional lab report. A synopsis report is one page and much like an abstract. It leaves out setup, procedures and measurement results. Students liked the synopsis reports more than the traditional reports and felt they gained deeper learning from them. Synopsis reports are obviously faster to grade than lab reports, thus providing students with more timely feedback. Hicks, Bruner & Kaya [9] used blogging instead of lab reports. The students described their findings in their own words and with a 20 s video. They were expected to read and comment on other students' blogs as well. Students thought the blog increased engagement, learning and collaboration. Cranston & Lock [10] described how students plotted their results during the laboratory on a large, wall-mounted graph with the exact solution. Then the students could immediately see how their results compared to other's results and the actual solution. During the session, students also completed a clicker quiz with immediate feedback on the correct results and how their replies compared to other students' replies.

The type of assignment chosen will obviously affect the workload of a course. Generally, down-scaling report writing will decrease the workload [6, 12, 13]. It is important to make sure the workload of a course is reasonable in order to help students acquire and understand the material covered in a class [15–17]. However, an estimate of workload in laboratory sessions and assignments' influence on workload in the laboratory component is sparse in the literature. The authors of this paper, therefore, have few studies to rely on in their pursuit of the ideal assignment form.

2.2 Feedback

Student assessment in any level of education needs to be learning oriented [18] and has traditionally been split into two categories, formative and summative [19]. Formative assessment is meant to guide the student to further improvement in their learning, whereas summative assessment is performed in order to assess the students' ability and ranking with other students. For feedback to support learning, it needs to be fast, directed to students' needs, specific, understandable, balanced, concise, personal, in the format that best fits the student and include follow-up [19]. In formative assessment, feedback is the most important, and giving a grade can actually demotivate the student to engage with the feedback [20]. In summative assessment, the grade is the most valuable, and feedback is often only used to justify the grade. Formative assessment is one of the main factors in improving students' learning outcomes [21]. Formative assessment has especially been found to improve the learning of students who are the weakest academically. The importance of formative assessment comes from the fact that students rightfully do not see it as a final verdict. It leaves open the possibility of everyone, not just the smart ones, doing well in the course if they put in the effort [22]. Peer review may be used as part of formative assessment and has been used successfully in university studies [23–27], but we found only two articles on peer review in laboratory courses [28, 29] in the literature. When deciding on the most appropriate assignment for each experiment, it is also important to decide on what type of assessment is most appropriate for each of those assignments. Shorter assignments will decrease the grading workload on instructors or teaching assistants, which will then conveniently decrease the response time of the returned assignment [6, 10, 12, 13]. Many laboratory sections often contain, often not explicitly, some form of formative assessment [6, 10, 11, 13] and peer review [28, 29].

3. Presentation

3.1 Setting the Scene

In the end-of-term teaching survey and informal talks from 2015 and earlier, students repeatedly voiced their dissatisfaction with the laboratory component of the FM course. They considered the laboratory section immensely time consuming and not helpful in their studies. The instructors, however, believed that hands-on experimentation would aid the students in grasping the FM concepts presented in lectures. Perplexed with the mismatch in instructors' and students' experiences of the

laboratory section, the instructors wondered if another schedule and assignment format would lead to greater learning with reduced workload. After all, the predicted workload of the course [30] was on the upper end of the intended workload. The laboratory component was five sessions, each three hours long, with a full report due from each group after each session. In addition to the laboratory, students in the class attended two lectures a week in a 14-week semester. One lecture consisted of three 40-minute sessions each with a 10-minute pause between. The other lecture consisted of two 40-minute sessions with a 10-minute pause between. The students also returned weekly individual homework throughout the semester.

In 2015 and earlier, the laboratory consisted of five three-hour sessions not aligned to lectures. In 2016, it was decided that the laboratory schedule would be altered to six one-hour sessions aligned with lectures. A short description of the experiments in the laboratory sessions is given in the appendix. In 2017 and 2018, a postlab in the lecture following the laboratory session was added to the course. Those changes are further described in [1] and reduced the students' workload and increased the students' understanding of the material. In order to further reduce the workload and increase the students' grasp of the learning outcomes the assignment format of the laboratory component was altered. In all cases, the assignment was a group effort. The number of students per group varied both between years and within the laboratory session each year from three to seven. A summary of the differences in the laboratory section in different years is given in Table 1.

In the laboratory component of the FM course in the fall of 2015 and earlier, students wrote full reports. A week after each of the five experiments, each group had to turn in a formal report with an emphasis on uncertainty analysis and derived uncertainty.

In fall 2016, the instructors made the first attempt to change and simplify the assignments. A worksheet for all experiments, with blank spots for the students to fill in the data, was prepared. The students were also instructed to prepare graphs to import into the worksheet. The worksheet also included specific questions, where the group was asked to interpret the results of the experiment. Special emphasis was on uncertainty analysis and derived uncertainty. An example of a worksheet for one of the experiments is given in Fig. 1. The length of the worksheets varied from three to five pages based on different experiments, but in the example provided, the white space was removed to give a more compact format for this paper. This reduced this worksheet from three to two pages. The work-

Table 1. Comparison of the laboratory sessions, 2014–2018

Laboratory component	2014	2015	2016	2017	2018
Number of laboratory sessions	5	5	6	6	6
Time (hours) per session	3	3	1	1	1
Laboratory sessions aligned with lectures	No	No	Yes	Yes	Yes
Number of students per group	3–5	3–7	4–5	4–7	4–6
Type of assignment format per laboratory session	Full report	Full report	Work-sheet	Short report	Excel sheet
Time to return assignment	A week	A week	Just after lab for first two exp. then 24 hours	A week	24 hours
Emphasis on uncertainty analysis	Yes	Yes	Yes	Yes	No
Type of grading	Grade and remarks	Grade and remarks	Only remarks	Grade and remarks	Grade and remarks
Additional assignment format in laboratory component	No	No	One full report graded with a grade and remarks based on a rubric available to students beforehand	No	No
Peer review	No	No	Yes, on full report based on a rubric	No	No
Postlab	No	No	No	Yes	Yes

sheets were in Icelandic but have been translated to English for this paper. Blank worksheets were provided to the students online in Word and Latex format. Each group returned the worksheet to the instructor in an email right after the experiment for the first two experiments and then 24 hours after the experiment for the last four experiments to give students more time. The instructor graded the worksheet within two to three days, so the group received their graded worksheet before they conducted the next experiment and could use the instructor's feedback to improve their next worksheet.

Instead of a grade, the group got a written description of the strengths and weaknesses of their solution and what steps could be taken to improve their analysis. A full score was given to groups that completed the worksheet. This was done to make the grading more formative for the students. In addition, the groups returned a full report on the second experiment in week four. This experiment was chosen because the students had done two experiments and received feedback on their analysis on those by then and the gap until the next experiment was five weeks. The groups received the feedback on the worksheet before they had to turn in the report.

In addition, peer review was introduced into the assessment process. The instructor designed a rubric and provided it to the students before the experiments for grading the report. The students first turned in their report for peer review. Each group

graded another group's report using the rubric, giving their peers a short written description of the report's strengths and weaknesses and how the group could improve the report in order to meet the requirements in the rubric. No grades were given in the peer review. The groups needed to return their reviews to the report's authors within one week. The students then had one week to improve the report before returning it to the instructor, who assessed them according to the rubric, including a grade.

In fall 2017, in response to the students' rather negative comments about using worksheets and peer assessment and due to changes in staff, it was decided to take a step back in the development of assessment practices. Each group wrote a short report for each experiment. The groups were not expected to restate the theory cited in the online instructions but rather to refer to those online instructions. Special emphasis was on uncertainty analysis and derived uncertainty. The groups returned the report within a week of each experiment. The reports were returned with detailed comments and grades.

In fall 2018, the instructors made tailored Excel sheets for each experiment. In all pre-marked green cells, students were asked to fill in measured values, and in pre-marked blue cells, students had to insert calculations based on the formulas from the online instructions. To simplify the analysis, there was no emphasis on uncertainty analysis, but the students who did a proper uncertainty analysis got a higher grade. In the Excel sheet, there was a large merged

Experiment 2 Stability of an object in static fluid			Discussion and interpretation of results		
Insert measured values with uncertainty into green boxes. Calculated values go into blue boxes					
Give the Excel sheet name "H1T1.xlsx" based on your group number and exp. number, where H1 is group 1 and T1 is exp. 1.					
All measurements should be in SI units					
Measured values			Measurements (add lines as needed)		
Variable	Value	Uncertainty	Weight at the bottom		Weight at the top
x			x	alpha	GM
P					
z					
l					
b					
h					
y					
rho					

Fig. 2. Example of an Excel sheet used for a laboratory session in 2018. Light grey boxes (green in the original document) are for measured values, dark grey (blue in the original document) for derived values and the big white box for interpreting the results

cell where the students were instructed to summarize and interpret the results. An example of an Excel sheet for the same experiment as the example of worksheet in Fig. 1 is given in Fig. 2. The Excel sheets were in Icelandic but have been translated to English for this paper. Blank Excel sheets were provided to the students online. Students returned the Excel sheet in an email to the instructor within 24 hours of the experiment. The instructor assessed the sheet with a grade and a short description of its strengths and weaknesses and suggestions for improvement. The grade was returned to the students within a few days, but always before the next experiment.

3.2 Methodology

To assess the consequences of changing the assignment format, various methods of collecting data were used. Those included the university's midterm and end-of-term surveys, a survey aimed at assessing the laboratory experience only, open-ended questions in the three surveys mentioned earlier and an analysis of a focus group interview with students on the laboratory component. The midterm and end-of-term surveys used covered 2014–2018. The laboratory focused survey spanned from 2015–2018, and the focus group interview was conducted once in 2018. Table 2 sums up the methods used to evaluate the changes in assignment

format. Participation in all surveys and the focus group was voluntary and did not affect the students' grades in any way. The instructors did not know who participated in the surveys. The students were told that the data in the laboratory focused survey and in the focus group would be used to improve the laboratory section and would, therefore, benefit future students in the course. A more detailed description of each survey is in the following subsections.

3.2.1 University Midterm and End-of-term Surveys

As a part of the centralized UoI quality assurance system, midterm and end-of-term surveys are held for all courses at the UoI. They are meant to assess each course and give feedback to instructors. In the midterm survey, students are asked to rate the course with a grade and also answer open-ended questions on what they liked about the course and what needed improvement. The results of the course rating are presented on a scale from 0–10. The university end-of-term survey consists of 24 questions, 15 of which are directly course related. Neither survey addresses the laboratory component of the course directly but gives the students the option of leaving comments on the course. Both surveys, therefore, have limited capacity to measure minor curriculum changes, and their results will only be briefly discussed in this paper.

Table 2. Measurement tools used to evaluate changes, 2014–2018

Measurement tool	2014	2015	2016	2017	2018
Midterm survey	X	X	X	X	X
End-of-term survey	X	X	X	X	X
Laboratory focused survey		X	X	X	X
Focus group interview					X

3.2.2 Laboratory Focused Survey

To assess students' attitudes towards the curriculum changes, a specific laboratory component survey was created. The survey was distributed online about a month after the final grades had been turned in and was monitored by the first author of this paper. In the four years studied, the only questions that varied on the survey were related to the assessment format since the assessments varied in those years. The survey included 6–10 mandatory questions (2015 had 6 questions, 2016 had 10 questions, 2017 had 7 questions and 2018 had 9 questions), five non-mandatory questions on demographics and an open-ended option where students could leave additional remarks. The purpose of the questions on demographics was to verify that the students responding to the survey closely represented the demographics of the student population taking the course. Since all questions in this survey were tailored to the laboratory section, the survey replies can be used directly for improving and developing the laboratory component.

3.2.3 Focus Group Interview with Students on the Laboratory Component

After reviewing and analyzing the replies to the midterm, end-of-term and laboratory component surveys from the last four to five years, a few questions were still unanswered or needed confirmation. In order to seek answers to those questions, a focus group interview with students on the laboratory component in 2018 was conducted. The focus group met once for one hour, two months after the last lecture of the course and about two weeks after the laboratory survey closed. Focus group participation was voluntary, and all students were given the opportunity to participate. Five students volunteered to participate: two from ME (third year), two from ChE (second year) and one from Engineering Physics (third year). They, therefore, represented the demographics of the course itself well. However, four students were female and one male, whereas in the course more students were male than female. The first and third author of this paper were present during the focus group meeting and led the inter-

view. The interview was audiotaped, and transcribed verbatim. The data were analyzed using thematic analysis [31].

3.3 Findings

In this section, the results of the various methods used to assess the effects of the changes in the laboratory section are presented. The total number of students and the percentage of the total number of students who participated in each survey each year is given in Table 3.

3.3.1 University Midterm and End-of-term Survey

The replies to the Likert scale questions in the university end-of-term survey show no clear indication of how the changes in the laboratory assignment format affected how students perceive their contribution, learning, workload or the organization of the course. As mentioned earlier, students' responses are based on the whole course, so the laboratory component may not be clearly indicated in those surveys. However, from reviewing the narrative replies from the 2014–2018 midterm and end-of-term surveys, it is clear that students' perceptions of the laboratory component improved as the years passed. In general, students went from thinking that it was too time consuming and not worth their time to thinking it was worth their time and even enjoyable. A portion of this change is due to the assignment format change and rescheduling of the laboratory component [1].

3.3.2 Laboratory Component Focused Survey

A comparison between years of the replies to the 5-point Likert scale questions in the laboratory component survey and to the perceived workload are given in Table 4 and Table 5.

As the years passed, students reported learning more from the laboratory component, with the exception of a slight dip in 2018, and they like it more every year. As for learning from the assignment, the students preferred the worksheet, short reports and Excel sheets over the full reports. The students in 2018 were asked if they thought they learned more from the Excel sheet than a report, to which the moderately agreed.

Table 3. The total number (#) and the percentage (%) of total number of students, who replied to each survey each year

	2014		2015		2016		2017		2018	
	#	%	#	%	#	%	#	%	#	%
Students in course	42	57	29	44	36					
Midterm surv.	18	42.9	23	40.4	11	37.9	20	45.5	22	61.1
End of term surv.	24	57.1	32	56.1	19	65.5	31	70.5	17	47.2
Lab. focused surv.	–	–	32	56.1	12	41.4	23	52.3	22	61.1

Table 4. Comparison of replies to the 5-point Likert scale questions in the laboratory component survey, 2015–2018. If a question or option was not included in that year's laboratory survey, it is indicated with –.

Question	2015	2016	2017	2018
I learned a lot from the laboratory	3.78	4.42	4.83	4.09
I enjoyed the laboratory	3.56	4.00	4.13	4.41
I learned a lot from writing the reports	3.59	–	–	–
I learned a lot from completing the worksheets	–	3.92	–	–
I learned a lot from receiving a short written feedback from the instructor on the worksheet	–	4.00	–	–
I learned a lot from writing one report	–	3.83	–	–
I learned a lot from reviewing a report from another group	–	2.42	–	–
I learned a lot from receiving a short written feedback from another group on the report	–	2.08	–	–
I learned a lot from writing short reports	–	–	3.96	–
I learned a lot from completing the Excel sheet	–	–	–	3.95
I believe I learned more from completing the Excel sheet than writing a report	–	–	–	3.50

Table 5. Comparison of replies on workload in the laboratory component survey, 2015–2018.

	2015 %	2016 %	2017 %	2018 %
Perceived workload				
Too heavy	28.1	16.7	0	0
Heavy	43.8	66.7	26.1	9.1
Just right	28.1	16.7	73.9	81.8
Light	0	0	0	9.1

The students in 2016 were not enthusiastic about the peer review aspect of the report. They did not think they learned from reviewing another report or receiving a peer review of their own work. The percentage of students who thought that the workload was too heavy during the laboratory sessions decreased with the changes in assignment and schedule [1] from 28% in 2015 to 17% in 2016 and zero in 2017 and 2018. With the worksheet, the percentage of students who thought that the workload was just right is still lower than in the unchanged format from 2015. With the short reports, the percentage of students who thought that the workload was just right went to almost 74%. When the Excel sheets were introduced, the

number of students who thought that the workload was just right increased to 82% with only 9% saying it was heavy, none that it was too heavy and even 9% saying that the workload was light in the first year of the four when that was reported.

In 2018, the students were asked how much time after the session they spent on completing the Excel sheet (Table 6). Half the students reported spending 2–3 hours, about 36% spent 1–2 hours, 9% spent 3–4 hours, less than 5% spent less than an hour and no students reported spending more than 4 hours on the Excel sheets. Instructors estimation of student workload in the laboratory component of the course was reduced to one third of the previous workload.

The replies to the demographic portion of the laboratory component survey (not shown) indicate that the students participating in the survey represented the demographics of the students taking the course well. Most students were full-time students, most did not have external work (a few exceptions report working full-time or more) and the majority of students did not have children. In most cases, external factors should, therefore, not influence their perception of the workload.

In the laboratory focused surveys conducted annually from 2015–2018, the students had the opportunity to answer open-ended questions. Annually, 4–15 students used this opportunity to comment on the course: 15 in 2015, 9 in 2016, 4 in 2017 and 6 in 2018. Aside from comments that focused on the course in general, the students raised concerns about the workload, assignment format, group work and uncertainty analysis of the laboratory component.

Table 6. Hours students reported spending on each Excel sheet outside of laboratory sessions shown as the percentage of students responding to the laboratory focused survey in 2018

Hour(s)	%
< 1	4.5
1 – 2	36.4
2 – 3	50
3 – 4	9.1

3.4 Workload

In 2015, most of the students' comments concerned the heavy workload of the laboratory component of the course. The students claimed that, although the experiments were "fruitful" and "broaden the spectrum on fluid mechanics", they were time consuming and did not "justify the time that goes into it". The reports were experienced as add-ons to an already busy homework schedule. As one student explained, they made coping difficult.

"When the laboratory component started, everything went wrong for me. I fell behind the coverage in lectures and became too busy with the laboratory sessions." (2015)

Students also addressed the heavy workload in their comments in 2016, where one suggested that the teachers "either give more time for post processing or reduce it". In 2017, the only comment on workload was positive. "I liked the workload, I heard it had been too much previously".

Assignment format

Students did not comment much on the assignment format in the open-ended part of the survey. In 2015, a student mentioned that they realized report writing was "important but cutting the reports to 2 instead of 5 would be more appropriate". In 2016, one student claimed that the new assignment format of worksheets was still as time consuming as writing reports.

"The only difference is that one does not have to think about formatting, phrasing or digging deeper into the literature." (2016)

Group work

In the open-ended replies from 2015–2017, students complained about the group size being too large with "free riders expected" (2016). In some cases, the group consisted of six or seven students, which made report writing particularly difficult.

"Usually 3–4 were working and 3–4 were not doing anything. Same applies to report writing. How should 7 people write a report together?" (2015)

"Groups of 6 do not work out! Always the same 2–3 people who did the report." (2017)

Uncertainty analysis

The only comment on the uncertainty analysis in the open-ended part of the laboratory component survey was in 2017. The student found the uncertainty analysis tedious but realized that their knowledge of it was limited and should be deeper for a student at the university level in engineering.

"I find it difficult and useless to derive uncertainty. . . . I have always been told to take just 1% of the value.

Which is, though, a bit ironic for university level." (2017)

3.4.1 Focus Group Interview with Students in the Fall 2018 Class

As stated earlier, five students participated in the focus group. The purpose of the group was to get better insight into students' experiences of the laboratory component. In the interview, students were asked to reflect on their experiences of the lab exercises within the course, the organization of the sessions and the assessment practices. Additionally, students were asked about the purpose of lab exercises and their learning.

Workload

In general, all the participants were quite satisfied with the laboratory component of the course. The organization of the laboratory component was favorably compared to labs in other courses where students complained of a lack of alignment between theories covered in classes and experiments done in the lab both due to a mismatch in time and to different teachers teaching each component. Whereas students in previous cohorts had complained about the excessive workload, the students in the focus group felt that the workload in the laboratory component was not too heavy, stating that, aside from the time used in the lab, the writing up process required only one to two hours of group work. Those replies are comparable to the ones in the laboratory component survey of that year.

Assessment format

Discussing the assessment format of the course, the students in the focus group claimed that they liked the Excel format. The assignment instructions were described as clear, not leaving students in any doubt of the steps required to carry out the reporting.

"[The Excel sheet] was so concise and focused. I always knew how to proceed; it didn't take multiple hours digging up some hidden truth." (focus group 2018)

The lack of writing a full lab report was not seen as problematic and adding report writing to the FM course was unnecessary. Students claimed that they had ample opportunities to practice report writing in other courses within the bachelor program and felt that they were neither "missing out" in report writing skills nor learning less.

"I believe we learn as much fluid mechanics, even though we skip report writing." (focus group 2018)

In assessment planning, students were provided 24 hours to complete and hand in their group assignment. Due to the time restrictions, students often worked on the assignment following the laboratory session if possible. Some said that 24 hours to return

was enough, but others said that it was sometimes hard to fit the assignments into their already packed schedules of work, sports and other classes. So, having 48 hours to return the assignment would have made their life less hectic. On the other hand, students preferred 24 hours return over the usual practice of handing in their assignments within a week, claiming that too much time between lab sessions and returning the reports often resulted in procrastination.

Group work

In the surveys, some students voiced their complaints about the number of students in each group. The participants in the focus group were asked about their experiences of group work. They had all been in a group of four and felt that was the appropriate group size.

“I was in a 4-student group and that was appropriate.” (focus group 2018)

Students stated that having one teacher per group gave room for good group discussion while carrying out the experiment but that writing up the results afterwards made it difficult to engage all group members.

“Four people in the experiment is fitting, but 4 people working on the Excel sheet is too much.” (focus group 2018)

Students did, however, claim that that the group size did not encourage free riders.

“I didn’t experience any free riders. Some weeks I did more, some weeks less; it evens out.” (focus group 2018)

Purpose of laboratory

When asked about the purpose of the laboratory component, students mentioned a few. First, the purpose of the laboratory component is to increase their understanding of the material covered in the course “by providing a link between often abstract theories and ideas and how things work in reality”. Therefore, as some stressed, it was important to align the material covered in class with laboratory exercises. Related to that, students also said that the laboratory component’s purpose was “to convince them that what is taught in class is actually correct and real and not just formulas on paper”. Another purpose was preparation for future work in the field. To become an engineer requires certain skills and those skills should be attained within the program.

“Well, I have heard about people who finished their engineering studies and go out into the work field. And the engineering companies are saying: ‘Did you learn this in university – No – did you learn this? – No – so

you are learning these skills at work rather than at school.’”

Finally, some students in the group claimed that the purpose was not only cognitive or vocational, but that laboratory components were the fun part of the studies, if the laboratory classes were organized and run in a decent way.

When asked about what learning they had acquired after finishing the laboratory component, students first answered that it was “the ability to think about how the theory works in the real world especially since exact measurement of the value is never achieved”. They then mentioned it had “taught them to assess error and where it originates”. They also claimed learning “how to work in groups consisting of others than just their friends as expected in a workplace” was valuable. The laboratory sessions also “increased their knowledge of Excel”.

An interesting issue was raised in the focus group interview. Whereas the focus of the educational development of the course had been on easing the students’ workload by various means, one of the participants questioned the demands of the assignment format on students’ higher order skills:

“It would be good to add thought-provoking questions to the analysis.”

Although this aspect was only voiced by one participant, it is a criticism that needs to be considered. Is the assignment challenging enough for students?

4. Discussion

Based on the analysis of all data collected, the laboratory component became more engaging for students with the changes made in it, and more importantly, they reported learning more from it. Expectedly, the effects of the changes were best detected in the laboratory component survey and least detected in the Likert scale questions from the university end-of-term survey. Students perceive that they learned equally from the Excel sheets, short reports and worksheets, but less from preparing a full report. The Excel sheet format seemed to be most liked by the students. The formative peer review introduced as a part of the course in fall 2016 was disliked by the students, contrary to what was expected and has been documented in the literature [23–29]. A possible explanation for this may be because the peer review itself did not count towards students’ final grades, the significance of the peer review was not explicitly explained, and students were only given short descriptions and not explicitly shown how to do a peer review. Those are all factors found to be important for a successful peer review

[29]. Therefore, students experienced it to just be additional workload that did not count towards their studies. They, therefore, may have put little emphasis on it and missed the opportunity to use it as a learning opportunity.

The focus group expressed satisfaction over the laboratory component while having some useful comments on how to improve it further. The students in the focus group liked the Excel format and said they learned as much about FM from it as they would have had from writing a report. They also believed that they learned enough about report writing in other courses in their BSc studies. The students in the focus group spent one to two hours completing each Excel sheet. This means that many students were getting close to Grant's ideal time frame of spending at most two hours on an experiment and its analysis [11]. However, they would have liked to have had 48 hours to submit the Excel sheet. Judging from the focus group on the laboratory component, students seemed to be achieving the learning outcomes aimed for in the FM course plus a few not specifically intended learning outcomes.

It is now appropriate to recall the research question listed at the beginning of the paper.

- What is the most appropriate assignment for each experiment with respect to workload and learning in the FM course?

If seeking an appropriate assignment format for each experiment with respect to workload and learning in the FM course, one can rule out a full report, but the Excel sheets seem to slightly outperform the worksheets and short reports. However, it would be worth exploring other assignment formats to see if more appropriate ones can be found and implemented. The various assignment outputs listed in the literature [6–13] would be worth testing and comparing to the Excel sheets in an extended research study. Furthermore, it could be beneficial to vary the output format from one experiment to another and look into giving students more options in regard to the assigned output.

The new assignment format has many advantages but is not without flaws. Moving away from having the students write a full report means that the students don't get the exercise of writing one in the course. However, the students do get this exercise in other courses in their BSc studies, and they feel like that is enough, although this assumption should be tested and discussed within the program. In 2016, the instructor spent much time and effort in making worksheets to reduce the workload on the students but still maintain the same learning gains. The students, however, felt like the worksheets were as much work as full

reports, possibly because they were not used to them and were more trained in report writing. Therefore, the instructor's increased workload did not lead to any gain. However, the Excel sheets were much simpler to produce and were also perceived by the students to reduce the time spent on the assignment. So, sometimes simple solutions lead to the most gain and great effort may also lead to minimal gain.

The analysis in this paper has its limitations. The number of students participating in the study is small, and it should be repeated on a larger group or within more courses to see if the results can be replicated. The number of students in the focus group was low, and the focus group was only conducted once. Since the instructors are also the authors of this paper, the views of the instructors have already been explored. However, the views of the laboratory technician on the changes in the laboratory sessions should also have been explored. There is no statistical analysis of the results presented in this study. Therefore, there is no verification that the differences in the students' perceptions of the different assignment formats is statistically significant.

The study is based on students' perception of their workload and learning gains and not on direct measurements of either. Even though it is clear that the changes in assignment format reduce the workload, a measurement of the actual workload of each assignment format would add to the findings. Also, even though the authors believe that and the students reported that the same or better learning happened from the new assignment formats as supposed to a full report, the learning need to be directly measured to be certain that the instructors' and students' perceptions are correct. Students test results are difficult to compare as student cohorts can vary both in academic status and interest. Despite those limitations, we believe this study's findings give a good idea of what assignment format is most appropriate in laboratory sessions and a solid foundation for further study on the subject.

Besides directly and immediately helping the students taking the FM course, finding an appropriate assignment format can have more profound implications. Reducing workload while maintaining or increasing learning increases student satisfaction, as shown above. Increasing student satisfaction has been linked to increased student motivation in their studies [32] and increased retention rates in higher education [33–36]. Dropout rates are high in many universities and are especially high at the University of Iceland. Therefore, actively taking steps towards minimizing dropout rates, however small they may seem, needs to be on everyone's radar. All efforts in improving teaching

and students' satisfaction in higher education, therefore, need to be encouraged [37–40].

Finally, the findings of the study provide information that could and should be an input into a broader, program-based educational dialogue on the purpose, learning outcomes and structure of laboratory learning at the University of Iceland. Such program-wide dialogues on the curriculum, although rare [41], are becoming more important due to institutional and external stakeholders' requirements [42] and students' demands. Engineering programs are, therefore, searching for a more integrated curriculum. Students' experiences and learning paths through the engineering programs [43] need to be explored further and researched holistically in order to ensure that the engineering curriculum offers the quality education and experiences that students need.

5. Conclusion

After analyzing the various data collected (university midterm, university end of term and laboratory component focused surveys along with a focus group), it is clear that choosing an assignment format other than a full report leads to a reduced workload while students perceive that the same or greater learning has been achieved. What assignment format is optimal is still up for debate and will be an interesting future quest. In this paper, full reports, worksheets, short reports and Excel sheets were tested. All forms that were not full reports were perceived by students as having similar learn-

ing gains, but the Excel sheets seem to lead to the lowest workload and are generally perceived to be more positive than other assignment forms. Relying on the replies of the focus group, the laboratory component with the Excel sheet assignments gained all the intended learning goals of the laboratory component and more.

Challenges in teaching are easily ignored by busy academics at the sacrifice of a significant lack of learning for students. It is, therefore, essential to listen to students' concerns, test the validity of their complaints and seek solutions. When searching for such solutions, it is crucial to do so in a scholarly manner, bearing in mind the intended learning outcomes and what is an appropriate workload for students, searching the literature for existing solutions and measuring all possible aspects and changes. Despite the considerable time and work needed to reach such a solution, the size of the possible gains make it well worth the effort. It is, however, also worth keeping in mind that a solution to a teaching problem is seldom final but part of a never-ending iterative process with hopefully ever-increasing gains.

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Appendix

In the laboratory component of the fluid mechanics course at the University of Iceland, six distinct laboratory sessions are undertaken: static fluid pressure force, stability of an object in static fluid, Reynolds experiment, pressure drop in a pipe, wind tunnel and viscosity of liquids. Those experiments are chosen because they touch on most of the material covered in the FM lecture and all the apparatus has been renovated within the last five years. A short description of each experiment is given below.

In the **static fluid pressure force** experiment, students increase the water level in a tank and simultaneously add a load to a lever. The momentum of the added load, along with the distance from the lever to the center of gravity of the area under water, is used to determine the static fluid pressure force on that area.

In the **stability of an object in static fluid** experiment, a raft floats on still water. By measuring the center of gravity, the center of buoyancy and the angle of tilt produced while a load is offset from the center of the raft, the distance from the center of gravity to the metacenter is determined.

In the **Reynolds experiment**, students observe flow in a transparent pipe with an indicator showing the streaklines. The transition between laminar, transient and turbulent flow is determined by varying the volume flow rate. Measuring the volume flow rate, the transition Reynolds number is determined.

In the **pressure drop in a pipe** experiment, students work with a pipe bench. They measure the pressure drop in a pipe for various flow velocities and compare these to the theoretical values using the Moody graph. In longer (earlier) experiments, three pipes were explored, but the shortened experiments used two pipes.

In the **wind tunnel** experiment, the drag force on various objects in a subsonic wind tunnel is measured and compared to the theoretical values. In longer (earlier) experiments, four objects were explored: sphere, disk, concave hollow half sphere and convex hollow half sphere. In the shorter (later) experiments, only the sphere and disk were used.

In the **viscosity of liquids** experiment, the viscosity of three unknown liquids is determined by measuring the terminal velocity of tiny spheres free falling in the still liquids. Terminal velocity is achieved when the drag force on the spheres and gravity are in equilibrium. From the measured viscosities, students determine what liquids are used in the experiment.

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