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Mastery Based Learning in Automatic Controls Class

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Mastery-based homework in Automatic controls class

Abstract:

In Automatic Control course at Minnesota State University (MSU) University, traditional homework still formed majority of learning experience. In Fall 2020, homework has been split into two components, the first (Category 1) dealing with the first three levels of Bloom's taxonomy, and the second (Category 2) dealing with the upper three levels. Category 1 homework has been administered electronically and as Mastery-based, while Category 2 remained traditional. A concept inventory developed is used to assess Category 1 level outcomes. Results are compared between Fall 2019 and 2020. Results indicate statistically insignificant differences due to small class size, but educationally significant results. An anomaly in incoming student quality, as measured by performance in pre-requisite course, complicated analysis. Further work will be conducted to study long-term effects of such implementation.

Introduction:

In engineering courses at Minnesota State University (MSU), traditional homework still forms majority of learning experience as well formative assessment. Even when traditional homework is graded and returned the next class period, a time lag happens in the feedback loop. Homework is usually treated as formative rather than summative assessment, as expressed in [1].

In this paper, the effect of converting some of the homework to Mastery-based in the course Automatic Controls is discussed. Converting all homework questions to Mastery-based learning is thought to impede learning due to insufficient tools in current learning management systems (LMS) to address certain analyze-level, evaluate-level, and design-level questions. All problems were categorized using modified Bloom's taxonomy ([2],[3]). Problems in levels 1-3 of Bloom's (remember, understand, apply) were assigned as Mastery-based, while problems in levels 4-6 (analyze, evaluate, create) were assigned as traditional homework. The reason behind this is that, while problems in levels 1-3 are easy to grade using computerized grading, problems in levels 4-6 require manual grading. This is because answers to problems in levels 4-6 require detailed reasoning and sometimes, design decisions. Current LMSs are not capable of administering and grading questions in levels 4-6.

The purpose of this study is to address the following questions:

1. Does student learning improve due to this approach, as measured by a concept inventory?
2. Does student performance improve using this approach, as measured by DWF rates.
3. Does this help utilize the instructor time better?

To address these questions, appropriate theory behind the approach is discussed in the next section. Methodology of this paper is discussed in the section after, and results in the section after methods. Details about activities of students, time spent by students, and a survey of student opinions is also presented in the results section. At the end of the paper, some commentary is provided on the conclusion and on the future direction of this work.

Literature Review:

Mastery-based learning approach to homework has become popular in the last decade. This is part of competency-based accreditation that is gaining ground. There two components that are critical to mastery-based homework. One is quick feedback and the other is multiple attempts which allow fixing the work based on quick feedback.

Immediate feedback has been associated with improved learning, especially during formative stages of learning ([1]), when lower levels of Bloom's taxonomy ([2],[3]) objectives are met. The improved learning takes place due to two different mechanisms. The first one is due to immediate feedback for students, along with multiple attempts allowed ([4]). The second is due to a better understanding by the instructor of the shortcomings of students ([5],[6],[7]). The approach closes the feedback loop faster for both students and instructors.

Mastery-based quick feedback homework has been studied and shown to improve student performance in various STEM subjects such as physics ([8],[9],[10]), mathematics [11], statics [12], and dynamics [13]. The approach in this paper has been to use similar approach for problems dealing with lower-level learning outcomes of Bloom's taxonomy, while the problems dealing with higher- level learning outcomes have remained in traditional format homework.

Other form of rapid feedback items includes classroom response systems such as clickers and polleverywhere [14]. These methods are constrained by available class time, and hence tend to focus on problems that are easily solvable in class. The proposed approach is expected to alleviate this concern.

Methods

Study Population:

This study has been conducted with a population of 35 for Fall 2020 and 41 from Fall 2019. These are typical class sizes at MSU for ME 463, Automatic Controls.

Pre-requisites

Automatic Controls course at MSU is third and final lecture-based course in dynamics and controls. Students take Linear Systems during their junior year, while Automatic Controls is a senior-level course with Linear Systems as its pre-requisite. Modeling of linear system using ordinary differential equations is covered in Linear Systems, ME 341. As part of this study, study performance in the main pre-requisite course is analyzed. This is done to contrast the performance of Fall 2020 students in Automatic Controls with the performance of Fall 2019 students. It should be noted that Fall 2020 students in Automatic controls passed Linear

Systems in Fall 2019 and Fall 2019 in students in Automatic Controls passed Linear systems in Fall 2018.

Mastery-based and Traditional Homework Implementation:

The course structure for Automatic Controls for Fall 2020 has been changed from entirely written (Fall 2019) homework to a hybrid format. In this format, as described in Figure 1, the homework problems at the level of 1-3 of Bloom's taxonomy (category 1) were converted to mastery-based homework, while the homework problems at the level of 4-6(category 2) remained hand-written. Category 2 problems also included open-ended problems, where students choose their own parameters.

The first category problems were entirely administered using the learning platform D2L(Desire-2-Learn) while the second category problems were to be submitted electronically but solved on paper using analytical/numerical tools. The students were given unlimited attempts for category 1 problems. After each attempt, the students would know the questions they got wrong, without revealing answers. Most of the questions in category were "arithmetic question" type in D2L. Each of attempt of the same question yields different numbers, so the answer to the question keeps changing for each attempt. This way the students must understand the concept to score correctly on the question.

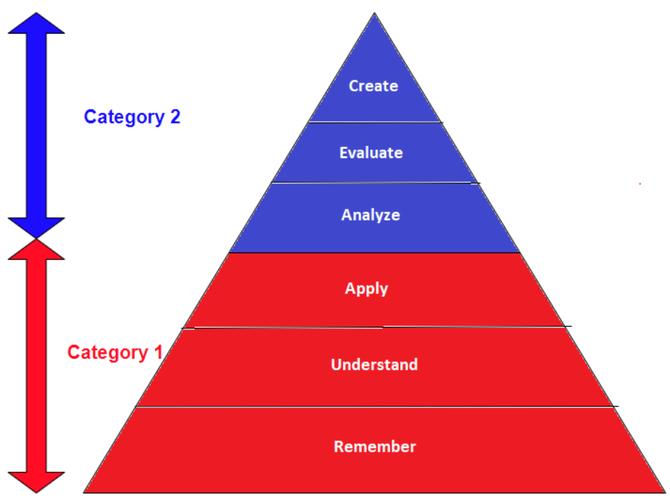

Figure 1: Categorization of homework problems

Category 1 had 20 homework assignments and a total of 54 problems while category 2 had 30 homework assignments and a total of 54 problems, as shown in Table 1. Sample problems belonging to each category are listed in Table 2.

Table 1: Number of homework and problems under each category

	Category 1	Category 2
# Homework	20	30
# Problems	54	54

Table 2: Sample problems from each category

Category	Question
1	Bandwidth(in rad/s) of a system modeled by the following transfer function is: $\frac{a}{s+b}$ Where a = 10.00, b = 1.00 Your Answer: Answer
1	A filter is used after a noisy sensor. The problem with choosing a low cutoff frequency is that ◯ PM decreases for CL system ◯ we may reduce the bandwidth of CL system ◯ all the above/below ◯ slower response of CL system ◯ increased overshoot
2	The open-loop transfer function of a unity-feedback control system is $G(s) = \frac{4K}{(s-2)(s+5)}$ Answer the following questions. a) Is the OL system stable? b) Find CLTF c) If the answer is no for part (a) then what value of K makes the CL system stable? d) What value of K makes the system stable with a damping ratio of 0.5. Confirm by plotting step response and analyzing overshoot. e) Plot the closed loop poles of the transfer function for $0<K<\infty$ (large number). Pick five different values of k. CL poles are labeled with a boxed X. Clearly label gain for each set of poles.

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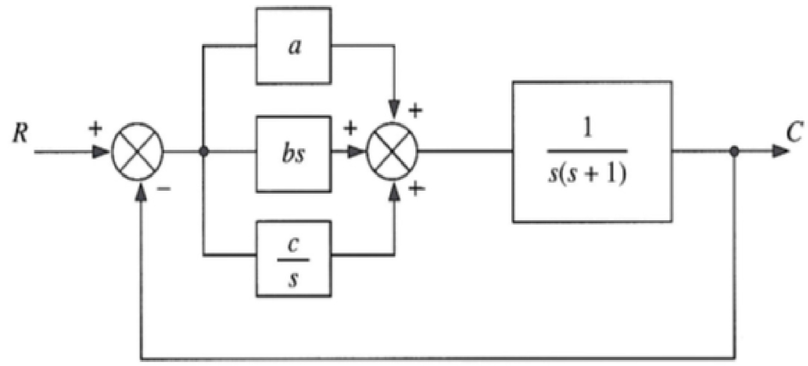
Consider the following feedback system.



Select the simplest values of coefficients a, b and c that will allow the closed-loop system to meet the following performance specifications (one system meets all requirements; a, b, and c are not different problems)

a) Zero steady-state error for a step input
b) A steady state error of no more than 0.05 due to ramp input
c) No more than 10% overshoot due to a step input

The transfer function before the plant [plant is 1/(s(s+1))] is PID control. Proportional, integral and derivative. You can use all three or any combination to make your problem work, you may also set a coefficient to zero if that simplifies things but try to meet requirements. Prove using MATLAB that you met the overshoot requirement, comment on any discrepancy you found, if you did.
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Assessment of Concepts (Category 1):

A concept inventory was developed in 2019 and was used to assess student learning for the semesters Fall 2019 and Fall 2020. A pre-test and a post-test were administered for Fall 2020. Since the concept inventory was developed during Fall 2019, there was no pre-test in Fall 2019, just the post test. Due to this, a representative comparison is not possible between Fall 2019 and Fall 2020. A comparison of post-tests between Fall 2019 and Fall 2020 is presented.

Overall Assessment

Students performance in Fall 2020 is compared with historic student performance. The metric for this comparison is the grade distribution. Students performance in a pre-requisite course, Linear Systems (ME 341) is also presented to put student performance from Fall 2020(controls class) in perspective with respect to student performance in Fall 2019(controls class). The same instructor taught the course, Linear Systems, in Fall 2018 and Fall 2019. It should be noted that students who were enrolled in Automatic Controls in Fall 2020 were enrolled for the pre-requisite in Fall 2019.

Students were administered a 5-point Likert-style survey at the end of the semester, to gauge student feedback on both categories. The survey also included questions about how long it took for students to solve each category of homework. A comparison of time spend by students on the two categories of homework is presented. The questions asked in the survey are listed in Table 3.

Table 3: Questions asked in the survey.

	Question
Q1	Master-based homework related to concepts covered in class
Q2	Mastery-based homework helped me better understand the material covered in class
Q3	I wish more engineering classes incorporated Mastery-based homework
Q4	I prefer the Mastery-based homework to traditional homework
Q5	My physical intuition about controls improved because of the Mastery-based homework
Q6	I enjoyed doing the Mastery-based homework
Q7	Mastery-based homework helped me better in preparation for exams compared to traditional homework
Q8	I am glad there is Mastery-based homework for this class
Q9	I wish there were only Mastery-based homework for this class

Results

At the end of the semester, results were analyzed to assess the impact of Implementing Mastery-based homework questions in an Automated Control course. Data collected included time spent by students on homework, for both traditional and mastery-based homework questions. Students' performance in concept inventory post-test is compared with that of previous year. Student performance for the two prior years in a pre-requisite course is discussed. Student performance in Automatic Controls course is compared with that of previous year. Finally, results from the survey are presented.

Distribution of time spent by students is shown in Figure 2. This data is from the survey administered to the students and this time is self-reported. The distributions are separated for the two categories of homework. The average for mastery-based homework is 42 minutes, while the average for the traditional homework is 86 minutes. The total time is 128 minutes on average. This is in accordance with the department expectation that, for each hour spent in class, two hours should be spent outside class in learning.

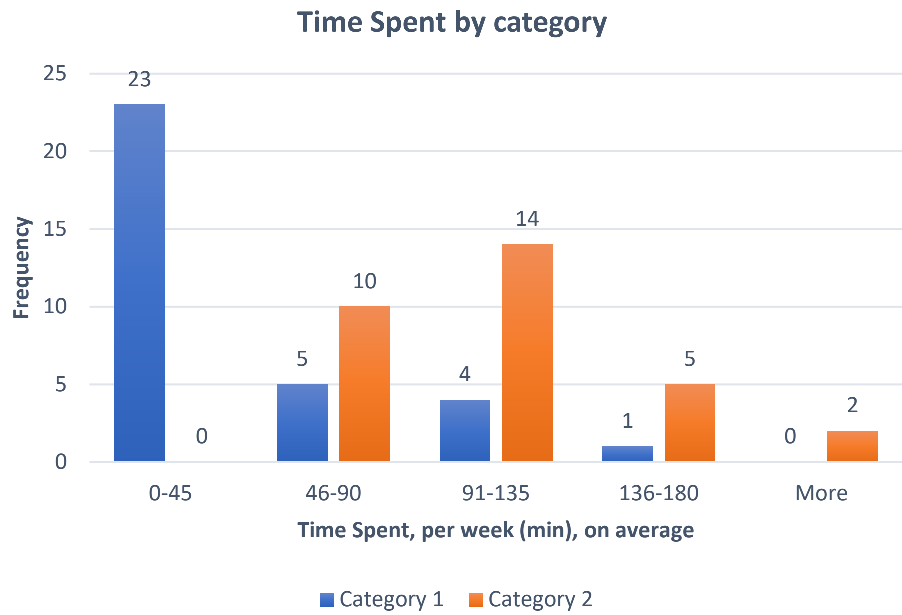

Figure 2: Time spent by category, per week, in minutes.

Grading time for mastery-based has been close to zero, barring occasional manual grading due to typos. This addresses the third question presented in introduction in the affirmative. The statistics provided by the D2L(Desire-2-Learn) LMS has been useful to identify trouble spots and fix them during the following class. Grading time has not changed for traditional homework, which included components such as analysis, evaluation, and design/creation. The author attests that moving the category 1 problems to D2L reduced the grading time of the homework, excluding the setup time on D2L.

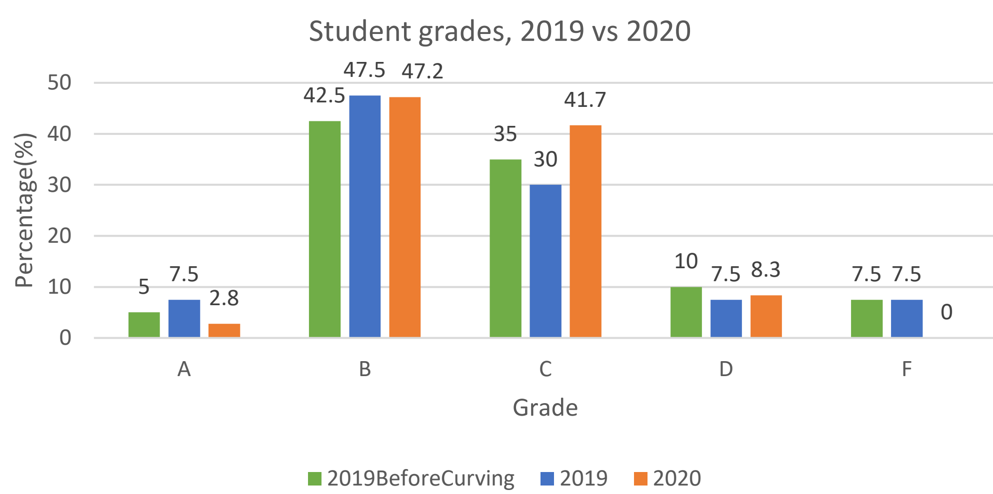

Figure 3: Student performance in Automatic Controls, as measured by a concept inventory.

Figure 3 shows student performance in Fall 2020 vs Fall 2019 in five equally spaced tiers. The concept-inventory part of the exam is directly based on the portion of learning levels covered by category 1 homework. In Fall 2019, there was no pre-test, whereas in Fall 2020 there was both a pre- and post-test. Comparing post-test results from Fall 2019 and Fall 2020, the median shifted from 3rd tier to 2nd tier. This is an improvement in Fall 2020. The performance of students in Fall 2019 was much better in both extreme tiers, compared to Fall 2020. Students in Fall 2019 scored an average of 62.2%, while the students in Fall 2020 scored 60.43%. This drop is not statistically significant (p=0.29).

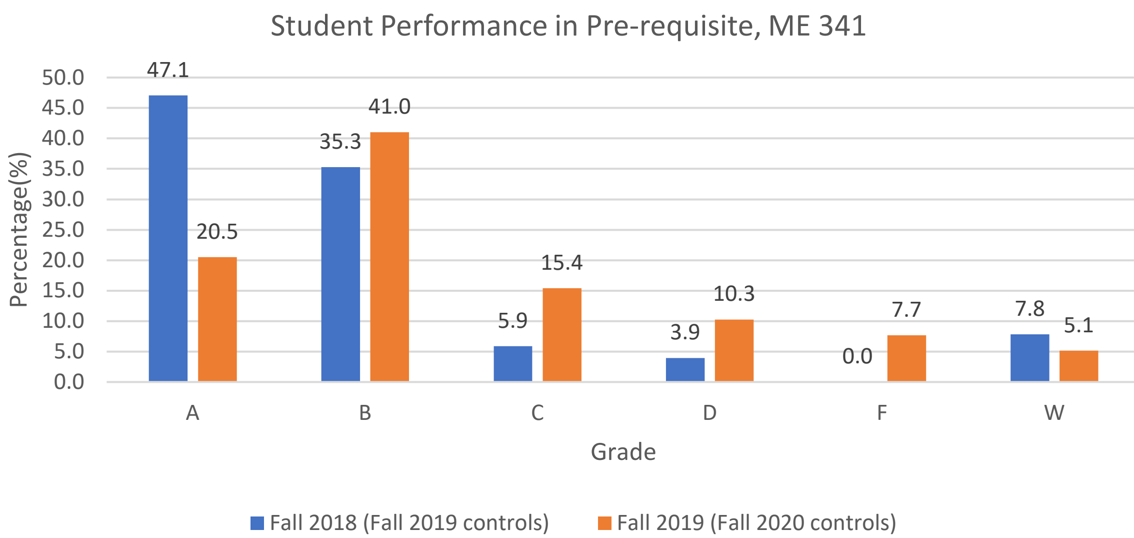

Figure 4: Student performance in pre-requisite course, ME 341

One factor that puts this data in perspective is the students' performance in the pre-requisite course shown in Figure 4. Based on the grades of these groups in the pre-requisite course, students who took Automatic controls in Fall 2019 performed significantly better in the pre-requisite, compared to students who took Automatic controls in Fall 2020. This can also be seen in Figure 5 by looking at historical performance for the course ME 341. Given the performance gap, it can be argued that there is an improvement in learning in Fall 2020 Automatic Controls cohort, but due to lack of pre-test data in Fall 2019 group, this conclusion cannot be drawn.

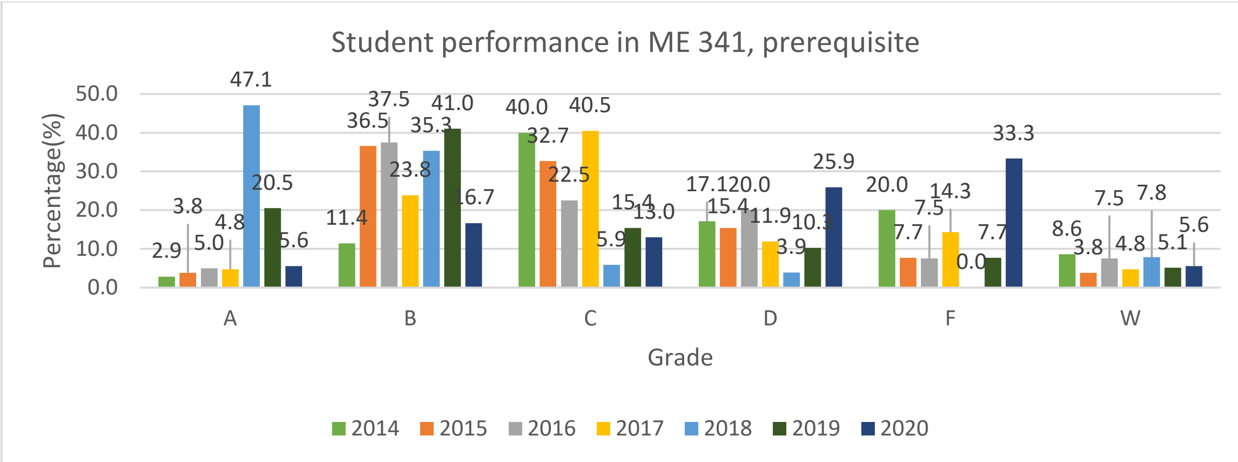

Figure 5: Historical performance of students in ME 341, the pre-requisite

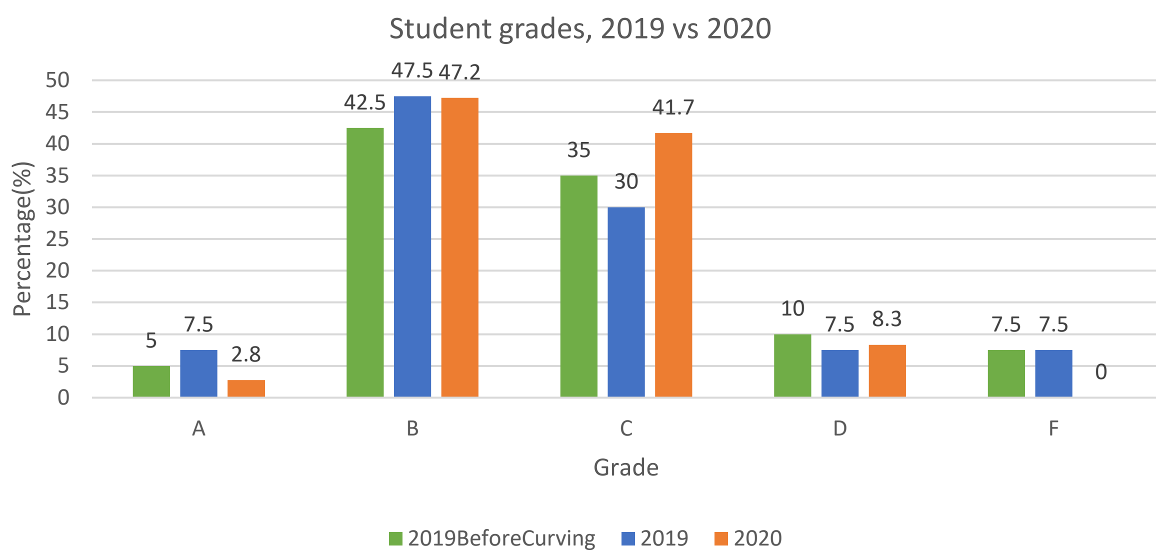

Figure 6: Student performance in Automatic Controls, as measured by course grades.

Students performance in the course is shown in Figure 6. The performance in the number of A grades dropped from 2019 to 2020. The number of B grades remained the same, while the number of C grades increased in 2020, compared to 2019. Another noticeable aspect is the lack of Fs in 2020. The distribution indicates that the grades got squeezed from 2019 to 2020. This resulted in decreased standard deviation. The course success rate, as measured by grade A, B, and C, however, increased from 2019 to 2020. In 2019, the course success rate was 85%, whereas this rate in 2020 was 91.7%. Due to small sample size, this difference is statistically insignificant. The p value is found to be 0.49 for the scores of entire populations.

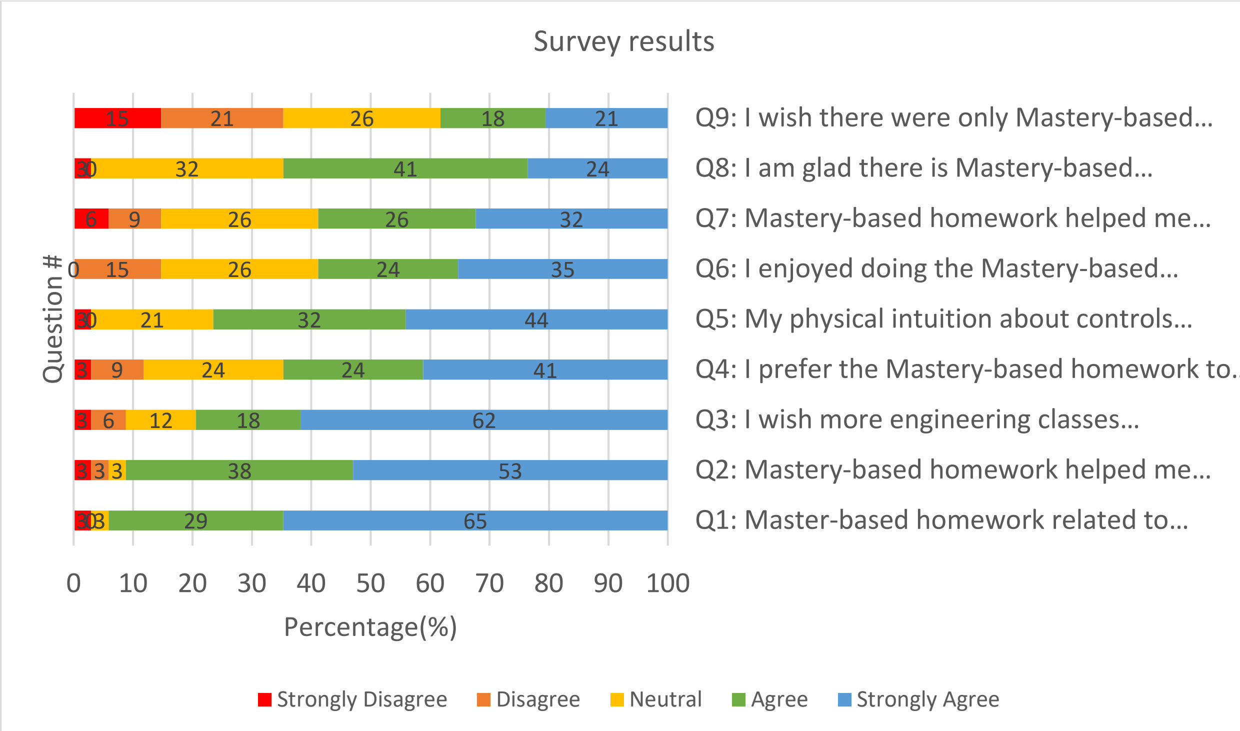

Figure 7: Student survey results by question

Students provided responses to questions about their perception and experience of mastery-based homework implementation in Automatic Controls in Fall 2020. The questions are found in Table 3. From the survey results in Figure 7, students clearly think the concepts topics are relevant and improve their understanding. Students also prefer mastery-based homework to traditional homework, arguably due to the fast feedback and multiple attempts. The students are lukewarm to the last question, possibly because they understand that higher-level questions cannot yet be effectively implemented using mastery-based homework.

Conclusion

Homework has been split into two categories, one spanning the lower level of learning outcomes and others higher, per Bloom's taxonomy. These categories have been administered, respectively, using mastery-based approach and traditional approach. A concept inventory is used to assess Category 1 learning outcomes. The course final grade is used to assess all learning outcomes. Students performance, as measured by concept inventory, from Fall 2019 to Fall 2020 has slightly worsened, although statistically insignificantly. The results are not entirely negative given the huge gap in students' performance in the pre-requisite course. Student performance as measured by course performance has produced a narrower distribution with better success rate, as defined by lower DWF rates. These results are also statistically insignificant due to lower sample sizes. The instructor time was better utilized due to automatic grading of a significant portion of the homework.

The study period has an overlap with Covid-19 pandemic since Fall 2020 students were affected by the pandemic while 2019 students were not. For this reason, a similar study will be useful after the pandemic subsides.

Future work:

Future work for this study should compare two groups in a class with one administered mastery-based homework, while the other only traditional homework. This, along with pre- and post-test will provide a better indicator of performance improvement due to quick feedback strategies such as mastery-based homework. Another similar study in the post-pandemic is also relevant.

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