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Exploring Motivational Tools for Homework in a Senior-Level Engineering Course

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Abstract

A number of instructional and pedagogical tools have been written about that focus on taking advantage of students' motivational strategies in learning activities. Over the past three years, a variety of tools and strategies were explored in a senior-level Aircraft Structures and Aeroelasticity course specifically targeted timely, thorough completion of homework assignments for understanding. Strategies explored include the use of late penalties vs early submission bonus points, flexible due dates, individual versus collaborative work policies and the use of homework templates to accomplish complex analyses. The effectiveness of late policies and bonus points was evaluated through a combination of homework scores, submission data such as lead time and the number of attempts. In addition, student perception was evaluated through the use of voluntary, anonymous mid-term and final course surveys. Qualitative faculty observations are included as well. Student response to the unlimited attempts on homework assignments was overwhelmingly positive. Initial data show that students achieve higher final scores on homework assignments when they attempt 1) the assignment earlier and 2) accomplish more attempts with a moderate correlation for both. It appears that 5% bonus points for early completion has a slight increase in motivation, for roughly half of students.

Background & Prior Work

This work intends to build on previous work on effective course design [1] [2] [3]. The strategies evaluated focus on student intrinsic versus extrinsic motivation. In this context, intrinsic motivation refers to motivation from personal interest [4]. Extrinsic motivation refers to those motivations created by the environment the student is part of [4]. Previous work has shown that positive incentives appear to have a positive effect on learning outcomes [5], that praise and reward were associated with higher extrinsic motivation [6], or conversely that negative incentives provided slightly more motivation for students [7].

Course Description

The course used in this study is a senior-level Aircraft Structures and Aeroelasticity course, which focuses on structural design and analysis of an aircraft wing. The course is entirely homework and project-based with no exams. Topics covered include generation of aerodynamic loads, shear & bending moment diagrams, normal stress, shear stress, compressive and tensile failure modes, vibrations, divergence, flutter and design for fatigue. All of the assignments are linked together to show the dependencies in structural design. Students are expected to build a suite of analysis tools using the homework assignments with analysis of a light-sport aircraft.

They are then expected to use the analysis tools they developed in their homework assignments to design the wing structure for a different aircraft in their design project. This scaffolded approach has them master skills lower in Bloom's taxonomy before progressing to higher level skills for their design work [8]. Homework assignments were individual effort whereas design project assignments were collaborative group effort assignments. In the current iteration, 800/1500 points are assigned to homework assignments and pre-quizzes, 700/1500 points are assigned to the design project submissions. The course is taught both Fall and Spring semesters with approximately 45-60 students in either two or three sections each semester. The course was taught by a single instructor for the duration of the study. The goal of the course is for all students to achieve 100% on the homework assignments through iteration and feedback so that they have a reliable design tool for their design project.

Homework description

As mentioned above, all homework assignments are linked together and are built upon one another. To accomplish this in a form that is usable for the aircraft design project, students complete all homework assignments within a single MS Excel template with an accompanying assignment document. For example, in HW#1 students build an aircraft V-n diagram (performance envelope) in the Excel template and calculate lift, drag and angle of attack at the four corners of the diagram. HW#2 requires them to use the lift and drag calculated in HW#1 to generate the wing free body diagram, shear and bending moment diagrams. This linkage continues through all of the homework assignments. Each assignment consists of a series of numeric answers used to validate intermediate and final calculations in the model the students build, as well as qualitative questions that ask them to exercise their model and gain an intuitive understanding/ build a mental model of the complex interactions in wing structural design.

Motivation strategies

Unlimited Submission attempts prior to the due date

For all of the semesters where data are presented a policy of unlimited homework attempts prior to the due date was used. Numeric answers were auto-graded in Blackboard and students received immediate feedback on these questions. Qualitative, short answer questions required instructor grading, which was typically accomplished within 1-2 days, giving students many opportunities for feedback and revision. This strategy was informed by Kortemeyer [9], who concluded that the optimum number of submissions for a physics course was five [9].

Late penalty and bonus points

For all semesters, homework assignments had a published due date on the syllabus, typically two lessons after the topic was covered in class. Two separate policies were used over the course of the study.

1. In the Fall of 2021, there was no late penalty associated with the syllabus due date. Students had the ability to submit assignments *up to the close of midterm grades* for homework assigned before midterms, or *up to the close of the semester* for homework assigned after midterms. Students received feedback on each submission and full credit. No submissions were allowed after the midterm/final close of grades. Assignments submitted after these dates were given a zero. This strategy was an appeal to the student's intrinsic motivation and desire to be prepared for their design project [10].
2. In the Fall of 2023, the strategy was revised. Students who completed the homework assignments with a score of 100% *by the published syllabus due date* were given a 5% bonus. Students still had the opportunity to complete the assignments by a "Last Chance" due date corresponding to the end of the lesson block, typically 4-5 lessons after the syllabus due date, but critically before the students needed it to complete their design project. This was a blatant attempt at using points as an extrinsic motivator for students [6]. Limited mid-course feedback is presented from the Spring 2024 semester which used the identical policies described for Fall 2023.

An excerpt from the course policy letter for each strategy is shown below:

Fall 2021: "Late work is not penalized, however it is in your best interest to keep up with the suggested due dates to avoid being swamped at the midterm and the end of the semester. You must satisfactorily complete all assignments with due dates before the midterm, before the midterm. You must satisfactorily complete all assignments with due dates before COB lesson 40, before COB lesson 40. Failure to do so will result in a zero score for assignments that aren't completed by these two due dates. Homework assignments are submitted online and unlimited attempts are allowed with no penalty for multiple submissions or late penalties. The purpose of this is to allow you to troubleshoot your analysis and develop reliable, useful analysis tools for use in your design project."

Fall 2023: "You must satisfactorily complete all homework assignments by the "Last Submission Date" listed on the syllabus. Failure to do so will result in a zero score for assignments that aren't completed by these due dates. However, if you complete the assignment with a 100% score prior to the "Homework Due" date, you will receive up to a 5% bonus on that assignment. Homework assignments are submitted online and unlimited attempts are allowed with no penalty for multiple submissions or late penalties. The purpose of this is to allow you to troubleshoot your analysis and develop reliable, useful analysis tools for use in your design project.

Demographic Data

Gender and race/ethnicity data were collected for both courses. Socio-economic, sexual identity and other demographic data were not available. The percentage of students by gender and race are shown in Table 1 as well as the corresponding values for the entire institution.

Table 1. Gender and ethnicity data for the two classes.

	Fall 2021		Fall 2023		Entire Institution
Gender	**Count**	**% of the class**	**Count**	**% of the class**	
Male	45	94%	46	87%	70%
Female	3	6%	7	13%	30%
Race					
Caucasian	45	94%	47	89%	75%
Black or African	1	2%	3	6%	7.4%
Asian/Pacific Islander	1	2%	1	2%	4.0%
Hispanic	1	2%	1	2%	7.3%

Data Examined

Two sets of data were investigated for this paper; 1) Number of homework attempts (and feedback received) versus final homework score, and 2) the number of days prior to the due date the student first attempted the homework assignment, referred to as "Lead Time" for the assignment versus final homework score. The hypothesis was that both number of attempts/feedback events and earlier lead time would correspond to higher final homework scores.

Results & discussion

Number of attempts versus final homework score

Because homework attempts were submitted in Blackboard, a digital log of submission attempts and corresponding scores was available for historical analysis. For each semester, the number of attempts for each student and each homework assignment was analyzed and plotted. Results are shown in Figure 1 and Figure 2.

In both cases, the more attempts and feedback a student had, the higher their final homework score. Conversely, students with a lower number of submissions had a lower average final homework score.

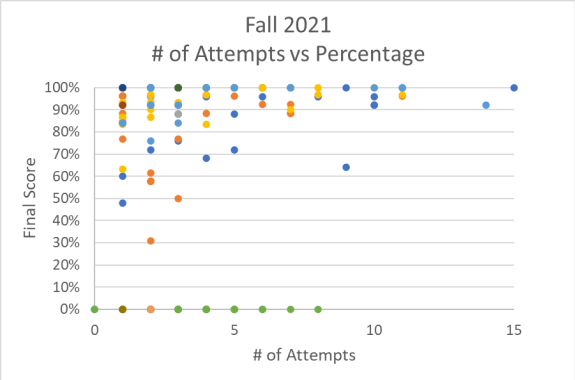

Figure 1. Fall 2021 # of attempts vs final score. Series with different colors represent different homework assignments.

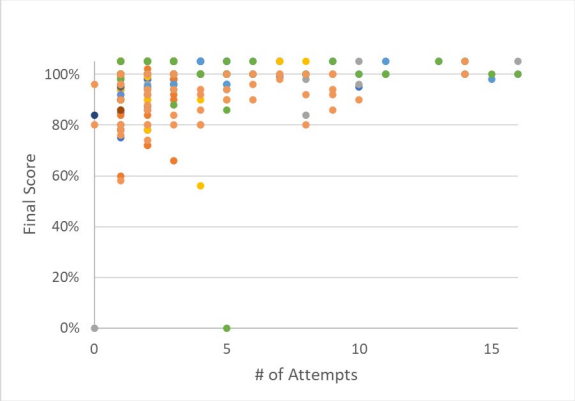

Figure 2. Fall 2023 # of attempts vs final score. Series with different colors represent different homework assignments.

Table 2. Number of attempts and final score data for the semesters presented.

	Policy	**Average # of attempts**	**Average score**
Fall 2021	#1	3.5	83%
Fall 2023	#2	3.7	96%

Table 1 provides a summary of the policy employed, the average number of attempts and average final homework score for both semesters. Note that the difference in percentage between the two cases is larger than the 5% bonus offered for completing the homework early.

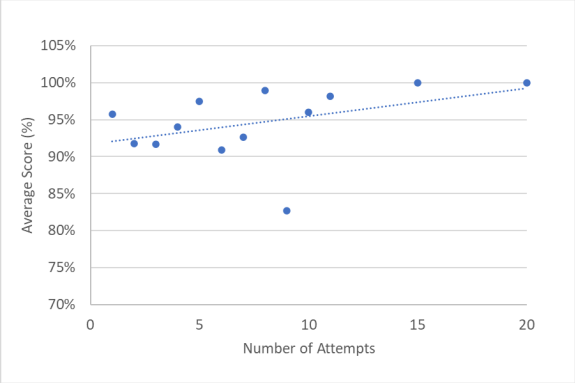

Figure 3. Number of attempts vs Average Score for all assignments, policy #1, Fall 2021. The overall average score was 91.7%

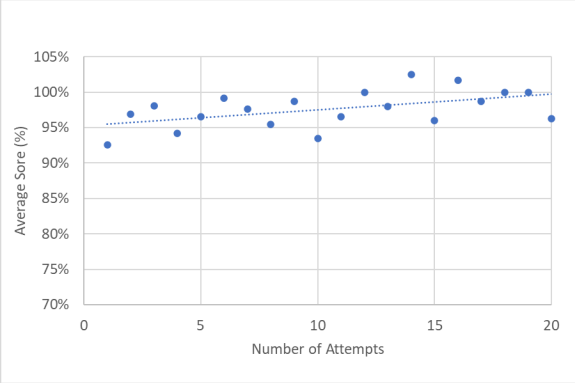

Figure 4. Number of attempts vs Final Score for all assignment for policy #2, Fall 2023. The overall average score was 95.7%.

Correlation data was also examined to determine if there was a relationship between # of attempts and final score. Figure 3 and Figure 4 show the plot of number of attempts versus average score for students with that number of attempts. Both figures have a linear trend line fitted to the data and show a slight upward trend in number of attempts versus final score. A

correlation analysis was accomplished on both data sets. The results were a correlation coefficient of 0.42 for the Fall 2021 semester and 0.59 for the Fall 2023 semester indicating a moderate positive correlation in both cases.

Lead time versus final homework score

In this section, between how early a student first attempted the homework assignment (Lead time) and that student's final score on the homework assignment were compared. In each case we looked at two due dates: the syllabus due date and the final due date. The syllabus due is typically two lessons after the material is discussed in class. For policy #1 (Fall 2021), the final due date refers to the close of grade for midterms or finals. For policy #2 (Fall 2023) the final due date refers to the "Last Due Date" published on the syllabus, typically 4-5 lessons after the material is discussed in class. In both cases submissions after these due dates received zero credit.

Fall 2021

This semester used policy #1 described above: unlimited submissions, no late penalty, submissions due prior to the midterm or final. Figure 3 below shows lead time vs final score based on the syllabus due date. The vertical line at zero represents the syllabus due date. Negative numbers indicate a student first attempted the assignment prior to the syllabus due date, positive numbers indicate a student first attempted the assignment after the syllabus due date. There does not appear to be a hard correlation between lead time and final homework score however it appears that most students first attempt the assignments closer to the syllabus due date. Interestingly there is a noticeable group of students who first attempt the homework assignment well after the syllabus due date who finish with a noticeably lower score. Average lead time for this semester was 5.3 days after, indicating most students first attempted the homework after the due date. Figure 4 presents the same date with lead time calculated from the final due date. Here a pattern emerges that students whose first attempt is closer to the final due date have an average lower score. Average lead time based on the final due date was 30.3 days prior. Average homework score for this semester was 82%.

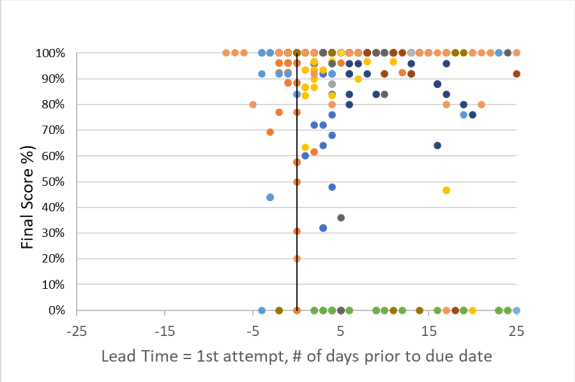

Figure 5. Fall 2021 Lead time vs score based on syllabus due date. Series with different colors represent different homework assignments.

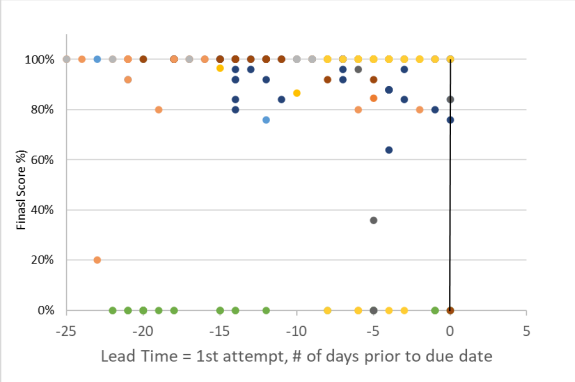

Figure 6. Fall 2021 Lead Time versus final score based on the Final Due date. Series with different colors represent different homework assignments.

Not captured in these data is the fact that completion of the homework was necessary in order to have a complete toolset to accomplish the design project. In many cases students had not attempted the required homework assignments when it came to accomplish the design project. In these cases, they relied on team members who had completed their homework assignments. In a few cases no one on the team had completed the homework prior to the design project submission date. This became apparent in the design project report write-ups.

Fall 2023

This semester used policy #2 described previously; unlimited submissions, bonus points for completion prior to the syllabus due date, no credit for submissions after the final due date. For this semester the final due date was 4-5 lessons after the material was covered in class, not at the midterm/final as in previous semesters. Figure 5 below shows lead time vs final score based on the syllabus due date. The vertical line at zero represents the syllabus due date and the last opportunity for 10% bonus points. Positive numbers indicate a student first attempted the assignment after the syllabus due date. Here we can see that nearly half of the class attempts the homework before the earlier due date and a number receive the bonus points indicated by 105% on the plot. Other than in bonus points, there does not appear to be a correlation between lead time and score. Average lead time for this semester was -1.7 days indicating a slight majority of students first attempted the homework after the due date. Figure 6 presents the same date with lead time calculated from the final due date. Once again, a pattern emerges that students whose first attempt is closer to the final due date have an average lower score. Average lead time based on the final due date was 9.9 days prior. Average homework score for this semester was 96%.

This semester, moving the final due date much earlier in the semester, and prior to when they needed it for the alleviated the problem of having students working on the design project who had not completed the homework assignments. The quality of design project reports was noticeably improved.

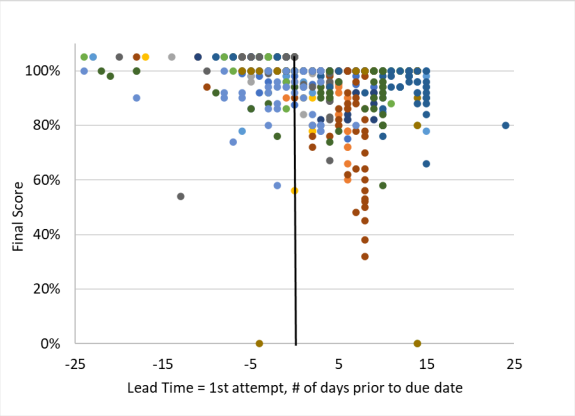

Figure 7. Fall 2023 Lead time vs Final Score based on the syllabus due date. Series with different colors represent different homework assignments.

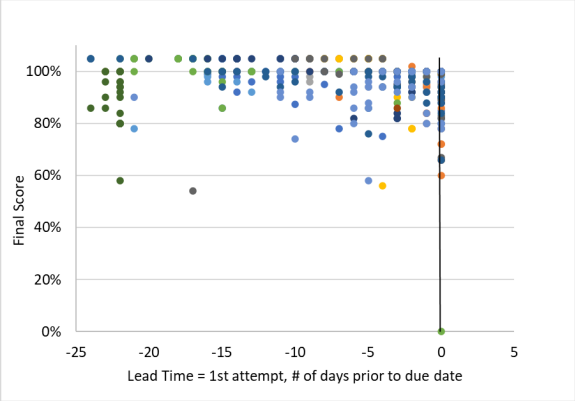

Figure 8. Fall 2023 Lead time vs score based on final due date. Series with different colors represent different homework assignments.

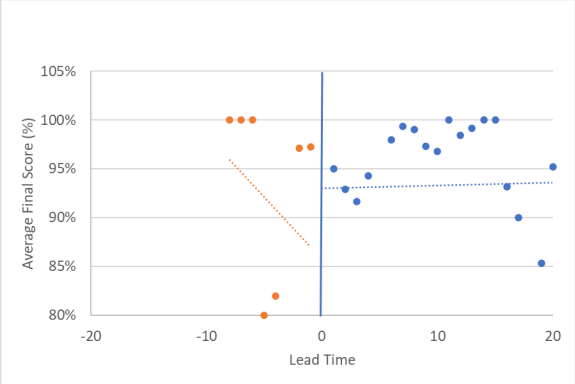

Figure 9. Lead Time versus final score for policy #1, Fall 2021, with accompanying trend line. The vertical at 0 is the syllabus due date.

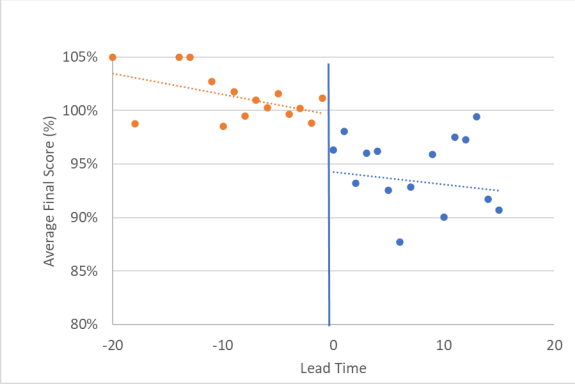

Figure 10. Lead time versus final score for policy #2, Fall 2023 with the accompanying linear trend line. The vertical line at 0 is the syllabus due date.

A correlation analysis was performed on this data to determine if there was a statistical correlation between lead time and final score. Results are shown in Figure 9 and Figure 10. In these figures, negative numbers represent first attempts before the due date, positive numbers represent first attempts after the due date. Both of these figures had the data set broken into two groups; students whose first attempts was prior to the due date are plotted in orange (negative lead times), and students whose first attempt was after the syllabus due date are plotted in blue (positive lead times. A linear trend line was fitted to both of these data sets. In both cases we see that, the earlier a student first attempted before the due date the higher the average score. Results for students whose first attempt is after the due date do not show a consistent relationship for the

two data sets. A correlation coefficient was calculated for these data sets as well. Results are shown in Table 3. Both semesters show a moderate to weak positive correlation between lead time and average final score for students who attempt the homework before the due date (early submissions). Conversely there is no correlation between lead time and average final score for students whose first attempt is after the due date (late submissions).

Table 3. Correlation coefficients for lead time versus average final score. Early submissions represent students whose first attempt is prior to the due date. Late submissions represent students whose first attempt is after the published due date.

	Fall 2021	**Fall 2023**
Early Submissions	0.29	0.49
Late Submissions	0.02	-0.11

Student Feedback

Student feedback was collected in the form of anonymous surveys at both the midterm and final for both offerings of the course. Although none of the survey questions directly addressed student motivation during the Fall 2021 or Fall 2023 semesters, there were questions directed at homework policy. In both surveys, students were asked to respond to the statement "The grading policy is effective in helping me accomplish the learning goals of this course." Responses were on a Likert scale with a range of 1-5. 1 was defined as "strongly disagree" and 5 defined as "strongly agree." Results are shown in

Table 4. Responses to the survey question "The grading policy is effective in helping me accomplish the learning goals of this course.: 1 = strongly disagree, 5 = strongly agree.

	Question average response	Standard Deviation
Fall 2021 – Policy #1	4.63/5.0	0.56
Fall 2023 – Policy #2	4.79/5.0	1.5

Numerical responses are not substantially different, perhaps because the question is stated so broadly. Students also provided written responses to the same question. Several representative examples are shared below.

During the Spring 2024 semester an additional survey question was added to the mid-course feedback. This semester used the same set of course policies described for the Fall 2023. Using the same Likert scale described above, students were asked to respond to the statement, "The homework bonus points policy motivates me to complete assignments prior to the due date." Results for this question are shown in Table 3. A complete set of data is not available for this semester since the semester is ongoing at the time this paper was written.

Table 5. Responses to the survey question "The homework bonus points policy motivates me to complete the assignments prior to the due date." 1 = strongly agree, 5 = strongly disagree

	Question average response	Standard Deviation
Spring 2024 – Policy #2	3.82/5.0	0.98

Student comments for the Fall 2021, policy #1:

> "Unlimited Attempts on Homework assignments to learn the material is a great course policy to allow me to learn the material rather than just complete it."
>
> "Flexible due dates are great! But also dangerous :)"
>
> "I really like how there is no "due dates." Often times I feel when I am struggling on something I try to push through something to get the answers without actually knowing how to do the process. with this mentality it really helps me feel less pressure by a due date and to take my time and actually figure out what is going on"
>
> "Unlimited Attempts on Homework assignments to learn the material is a great course policy to allow me to learn the material rather than just complete it."

Student comments for the Fall 2023 – Policy #2

> "Course policies are great, I get incentivized to do my homework early, and I have really learned a lot."
>
> "The due date policy is beneficial in deciding where I should spend my time. I like to think of it as the early due date is the bad cop, and the hard due date is the good cop. Not sure if that analogy totally holds true."
>
> "I am very in favor of the homework grading and policy. I think it's wise to allow students to submit multiple attempts and to freely receive feedback to improve our learning."
>
> "Course policies make the course extremely flexible for students to complete the course at their own pace. There is a lot of opportunity for bonus points if you are able to get ahead."

Student comments for Spring 2024 Midterm feedback – Policy #2.

> "The early homework policy does not motivate me to do things early because I have lots of work from other classes too. When I can either go to sleep at a somewhat reasonable time or complete [course #] homework early, I'll pretty much always choose sleep. I would be more motivated to do the homework early if the extra credit was worth more."
>
> "Course policies are fine, even generous. One of the best parts of the course."
>
> "I like the homework policies and I really appreciate the flexibility"

> "I really appreciate the opportunity for bonus points. It seems to destress things a bit."
>
> "I like the bonus for homeworks and the ability to receive feedback on them before they are due."
>
> "Love the ability to submit multiple attempts on homework assignments! I find it very useful!"
>
> "love the way the homework due dates are laid out and how we get feedback and can resubmit things to improve our products. I wish every class was like this!"

Discussion of student feedback

For both sets of course policies examined, student feedback was overall favorable when examining both Likert scale responses and student qualitative comments. The common theme for both sets of policies was unlimited submissions (and feedback) prior to the due date. This aspect of the policies was overwhelmingly well received. In fact no students gave feedback suggesting that a single-submission model was preferrable.

Feedback on policy #1 (unlimited submissions, no late penalty, submissions due prior to the midterm or final) showed that students appreciated the opportunity for unlimited attempts. However, the opportunity to procrastinate until days before the midterm or final grade deadline was a strong pull for many student. Many comments reflected the idea that less-than-optimal learning occurred as a result of the push to get homework assignment completed at the last minute. The resulting disconnect between needing the analysis tools developed in the homework assignment to complete the design project, yet not having completed the homework assignments in time to use them on the design project. was a common theme. Many groups relied on a single team member who had completed the assignments on time. Several teams did not have any team members who had completed the homework and their resulting design project submissions were sub-par.

Feedback on policy #2 (unlimited submissions, bonus points for completion prior to the syllabus due date, no credit for submissions after the final due date), was slightly more positive. Students appreciated having the choice to pursue bonus points, or not. Many of the student comments mention that the opportunity for bonus points was a motivating factor. In contrast to policy #1, nearly all of the students had completed the homework assignments prior to attempting the design project, so the resulting quality of work in the design project submissions was much greater.

The additional feedback collected on policy #2 in the Spring 2024 mid-course survey reiterated the across-the-board support for unlimited homework attempts. The addition, both numeric and text responses confirmed that the bonus point policy was a significant motivator for a proportion of the students.

COVID-19

The Fall 2021 semester was during the COVID-19 pandemic. The impact on engineering students emotional and academic performance is well documented and typically described as negative. [11, 12] While the course that is the subject of this analysis was taught in person, students had taken the two prerequisite courses online. One of the prerequisites was online and synchronous, the other was online and asynchronous. In the case of the two prerequisite courses, final grades were approximately 0.5 grade points lower in both courses than the historic average. The instructor noted substantial gaps in the student understanding.

The Fall 2023 semester was much further removed from COVID-19. These students typically experienced COVID-19 lockdowns as first-year college students. While there was still a gap in student understanding, it was noticeably less than the Fall 2021 cohort of students.

Implications for Practitioners

For faculty who are striving for a more learner-centered course or curriculum, there are small things that we can do to increase our students' chances of achieving the desired learning outcomes.

Many faculty have already transitioned their courses to a Learning Management System (LMS) such as Canvas or BlackBoard. The overhead required to build the initial course infrastructure can be time consuming but not overwhelming, and the payout is large. Furthermore, the tools can be reused in following semesters and just "tweaked" around the edges. In the long run they will save instructor time. More importantly, they have the potential to enable greater student learning through the use of multiple or unlimited assignment attempts with virtually no instructor workload. In the LMS used at this institution, Blackboard, allowing unlimited attempts is a simple radio button selection on the assignment.

Encouraging students to attempt the assignment before the due date increases scores and learning. There are many ways to accomplish this. A small amount of bonus points for early completion and mastery motivated roughly half the students in this study. Other techniques such as pre-class assignments or in-class work of assignments are other techniques that might be useful.

Simple policy changes can have a moderately positive effect on student learning. In my experience, many instructors simply rinse and repeat previous course policies without much thought. Incorporating the results of simple studies like this to make minor changes to policies can greatly increase student learning.

Often in faculty development we focus on the big topics without attention to small details such as those presented here. Incorporating these small details into faculty development seminars or new-faculty orientation can have a positive effect on student learning. Encouraging or even assisting faculty in developing their course using a LMS that enables online submission and rapid feedback is an investment worth making.

Conclusion

We drew three conclusions from this work:

1) Unlimited attempts and feedback on homework enable students to achieve higher final scores on those assignments with average scores of 82% and 96% for the semesters examined. A moderate positive correlation between number of attempts and final score (0.42 and 0.59) existed for both semesters examined. Student responses to this policy was overwhelmingly favorable in all semesters examined.
2) There is a mild positive correlation (0.29, 0.49) between the lead time (# of days before a homework is due that the first attempt is made) and the students final homework score. A longer lead time correlates to a higher score. A lower lead time correlates to a lower score. However this affect only exists for students who attempt the homework before the due date. For those who procrastinate and whose first attempt is on or after the due date, no correlation exits (0.02, 0.11).
3) 5% bonus points were a motivator for students to complete assignments earlier (3.82/5). While roughly half of students took advantage of the opportunity for 5% bonus points, many did not. Roughly half of the students in this data set did not attempt the homework assignments until the opportunity for bonus points had passed. Survey data suggests that some students are motivated by the 5% bonus points, while others are not.

Future Work

The data set is ripe with opportunities for more detailed investigation. One such topic is how well students perform who only attempt the homework once. A related topic is on procrastinators; how students perform who don't attempt the homework until the due date. There is the opportunity to examine the effect of 10% bonus points, 5% bonus points and no bonus points on student motivation to finish work early.

Including student perception of these policies would go a long way to understanding motivation. Survey data presented does not include specific questions on motivation, demographic or information about other factors in student life such as course load, family life, extracurricular activities, etc. These data has been added to mid-course data for the Spring 2024 semester and beyond.

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