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Student Earnestness in an Interactive Online Controls Textbook When Answers are Available

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Abstract

Interactive textbooks commonly engage students by embedding questions within the reading exposition to help students review concepts and identify misconceptions. While these questions often allow the students to view the correct answer, the assumption is that students will only view the correct answer after having unsuccessfully attempted the question. In actuality, how many students try the question before clicking to see the answer? The answer to this question is important because attempting to answer a question results in better long-term retention than simply reading the answer or solution.

In this study, student responses to unique formative assessment questions embedded in an online interactive control systems textbook (the *Control Systems Engineering* zyBook, based on the *Control Systems Engineering* textbook by Norman Nise) are evaluated from multiple classes across multiple universities. The study addresses three questions. First, do students make an earnest attempt at answering the questions when the answer is easily accessible? Responses are considered earnest if the student made at least one attempt at answering the question before revealing the solution. Second, do specific characteristics of the zyBook or course correlate with increased or decreased student earnestness in answering questions? These include characteristics such as: point of progression within the course and within a chapter, class size, institution Carnegie classification, and question difficulty. Third, are these student behaviors consistent between students in control systems courses, which tend to be upper-level courses, and students in circuit analysis courses, which tend to be introductory-level courses? We compare the results for the *Control Systems Engineering* zyBook to a similar earlier investigation in the *Basic Engineering Circuit Analysis* zyBook, and to earlier investigations in computer science zyBooks.

The resulting analysis shows more student earnestness on questions with particular parameters. Through this study, we expect to improve understanding of students' engagement with online interactive learning materials and factors that correlate with different levels of student engagement, to inform the further evolution of interactive textbooks.

Introduction

Textbooks used in engineering courses are typically chosen for topical coverage, level, and for how well the textbook supports student learning. Quality of student learning support is particularly important for engineering courses because engineering courses are challenging, with many courses having high failure rates. One institution found average failure rates (students receiving a grade of D or lower in the course, or withdrawing) of 23% for their introductory circuit analysis course [1]. Despite students themselves reporting knowing that it's important to read the textbook and that reading will improve their grades [2], many students still choose to skim or skip their reading assignments [3], [4].

Numerous studies have shown that format (digital vs. print) [5], [6] and interactive learning materials [7] - [9] improve students' learning, and so developers of textbooks, courseware, and online courses employ learning theory to make these tools even more effective [3], [10] - [18]. While there is a certain level of positive impact from interaction with the most common etext functionality like attaching bookmarks, adding/deleting markers, incorporating student notes, and navigating (next/previous/jumping) [1], content developers are striving for a greater impact. One of the ways content developers have tried to make textbooks and courseware more supportive of learning is by embedding questions within the main text, rather than as a separate or end of chapter set of questions. The embedded questions are intended to engage students actively, help students remember by practicing retrieval of what they've read, and identify and remediate misconceptions. In some products, the embedded questions are interactive and allow students to view the correct answer.

Content developers of embedded interactive questions may assume that students will only access the correct answer after attempting a question. Based on research, students following this process would improve their learning, as attempting a question results in deeper processing of the solution and better long-term retention than simply reading an answer or solution [19] - [21]. But, faced with significant time pressure, students may be impatient or may not recognize the benefits of active retrieval [19] and productive struggle [10]. Students may think that simply reading the answer or solution (without trying it themselves first) will be enough to be successful in the course, without having to work through problems themselves. Because they read the answer or solution and understood what they read, students may fall prey to an "illusion of knowing", a false sense of mastery [22], [23]. This illusion of knowing from reading also leads to students re-reading as a form of study, and the student belief that re-reading alone will lead to retention. But this sense of mastery from reading or re-reading is indeed false [19], [24] - [26].

One example of research demonstrating greater mastery resulting from answering questions compared with reading/reviewing occurred in an undergraduate course at a university in Germany. Researchers designed the study such that the last 10 minutes of seven lecture periods was used for reviewing the lecture content in one of three ways: 1) reading summarizing statements about the lecture content, 2) answering multiple choice questions, or 3) answering short answer questions. The students were then tested on that content with alternate versions of questions at different periods of time after the last lecture: 1, 12, and 23 weeks later. The researchers found that having answered short answer questions at the end of the lecture period had a significantly positive effect on student success in all of the follow-up tests compared to students who read and reviewed the summarizing statements [27]. This study suggests that when the answers to interactive questions are easily available, students who jump to immediately read the answers or solutions will not retain the material as well as students who first earnestly attempt to answer the questions.

So, how many students try the questions embedded in an interactive control systems textbook before looking at the answer? This paper evaluates student responses to interactive questions in the *Control Systems Engineering* zyBook across multiple universities.The paper addresses three questions. First, do students make an earnest attempt at answering the questions when the answer is available with a click? Responses are considered earnest if the student made at least one attempt at answering the question before revealing the solution. Second, do specific characteristics of the interactive textbook, course, or institution correlate with increased or decreased student earnestness in answering questions? These include characteristics such as: point of progression within the course and within a chapter, question difficulty, class size, and institution Carnegie classification. Third, are these student behaviors consistent between students in control systems courses (which are typically upper-level courses), and students in circuit analysis courses (which are typically introductory-level courses), or between different academic disciplines? We compare the results for the *Control Systems Engineering* zyBook to earlier investigations in zyBooks in circuit analysis and introduction to programming.

Methodology

This study evaluates student earnestness within the context of interactive short answer questions in the *Control Systems Engineering* zyBook. Usage data based on recorded clicks was obtained from the zyBooks platform and was analyzed for 3,163 students across all 68 institutions that used the *Control Systems Engineering* zyBook during a period of one year, with activity occurring from January 2023 to January 2024. Of the 68 institutions, 56 were in the United States, and 12 were in other countries, as indicated in Table 1.

Table 1: Number of institutions in each country included in study.

Country	**U.S.**	**Canada**	**Turkey**	**U.K.**	**Ireland**	**Netherlands**	**Norway**
Number of institutions	56	4	3	2	1	1	1

Of the 56 institutions in the United States, they were distributed regionally as shown in Table 2.

Table 2: Number of institutions in each U.S. region, as defined by U.S. Census Bureau.

U.S. region	**Northeast**	**Midwest**	**South**	**West**
Number of institutions	13	16	22	5

Data was available for chapters 2 through 13 (out of 13) of the *Control Systems Engineering* zyBook. Chapter 1 did not include any short answer questions so was excluded from this study.

In a short answer question set, the student types in the answer to the question in the specified short answer field. There are typically two to five questions that a student is expected to answer in a single question set. Student completion of a question set may count as a portion of the course grade at the discretion of the instructor. Figure 1 shows an example of a short answer question and the kind of feedback a student may receive after submitting a response in the zyBook. When a student clicks the "Check" button with either an incorrect answer or no answer, the zyBook provides a hint. Figure 2 shows the student user experience when a student clicks the “Show Answer” button twice.

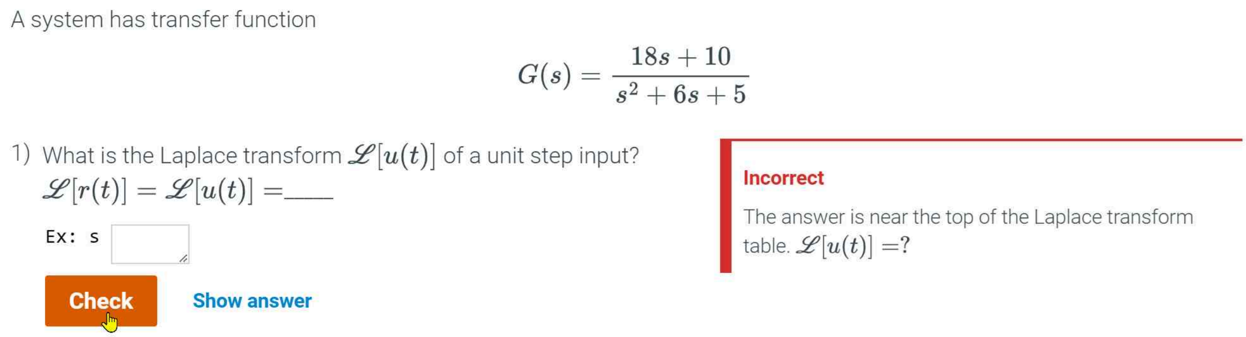


Figure 1. Example of a question providing a hint when the answer is incorrect or nothing is entered.

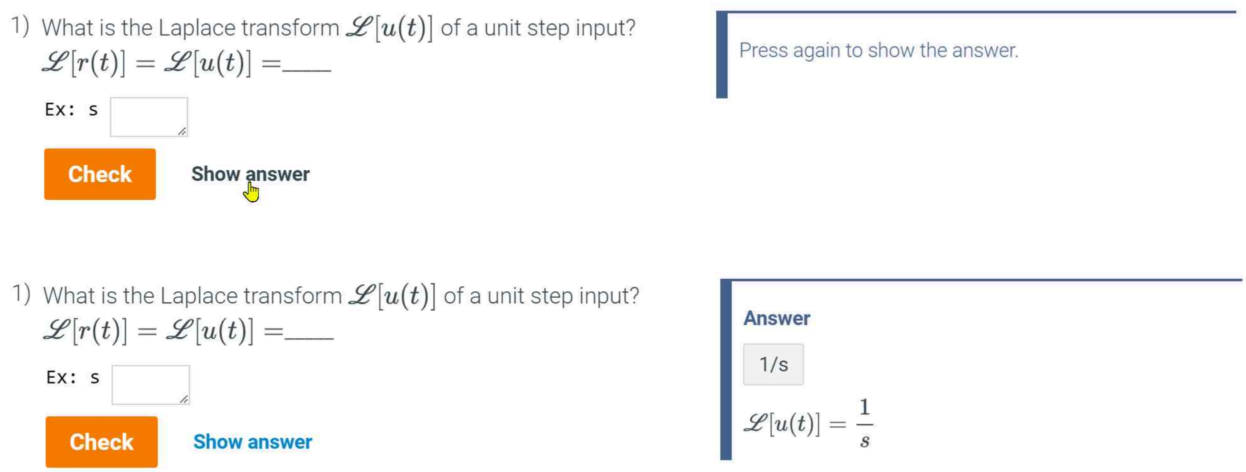


Figure 2. Example of a question when a student clicks the Show answer button twice.

Students may attempt the question as many times as they want. At any point, they can reveal the correct answer by clicking the “Show answer” button twice. Students must enter the correct answer to receive credit for completing the question. Students who enter the correct answer receive credit regardless of whether the answer was revealed via "Show answer" before being answered correctly.

Average student earnestness for questions, across sections, and across chapters was defined in a range 0-100%, representing the percentage of students who responded earnestly to a question. A response is considered to be earnest if the student made at least one attempt at answering the question before clicking “Show answer.” Blank answers are not counted as earnest attempts.

An individual student’s earnestness is calculated as:

$$E = \frac{Q_a}{Q_t} * 100$$

where Q_a is the number of learning questions for which a student made at least one attempt before revealing the answer, and Q_t is the number of learning questions the student answered.

In addition to earnestness, the study investigated the correlation of student earnestness with question difficulty, the length of time in the course, and the size of the class. Earnestness and data about progression in the *Control Systems Engineering* zyBook were obtained from the zyBooks platform.

Student earnestness was also evaluated versus the sections within each chapter. For brevity, we have provided aggregate results of earnestness based on section. The section one results are an aggregate of the results from all of the first sections of every chapter, the section two results are aggregated from all of the second section from every chapter, etc.

The effect of class size on student earnestness was also evaluated. Based on the results of earlier research for a circuit analysis zyBook [28], the authors expected class size would not affect student earnestness, and so conducted this analysis for completeness of comparison.

Finally, the study evaluated student earnestness relative to individual institutions, and to the Carnegie classification of the institutions (distribution shown in Table 3).

Table 3: Number of institutions in Carnegie classification pools included in study.

Carnegie classification	**R1**	**R2**	**Other**
Number of Institutions	12	18	29

Earnestness versus chapter number

Figure 3 shows the boxplot of earnestness versus chapters 2 to 13 from left to right respectively.

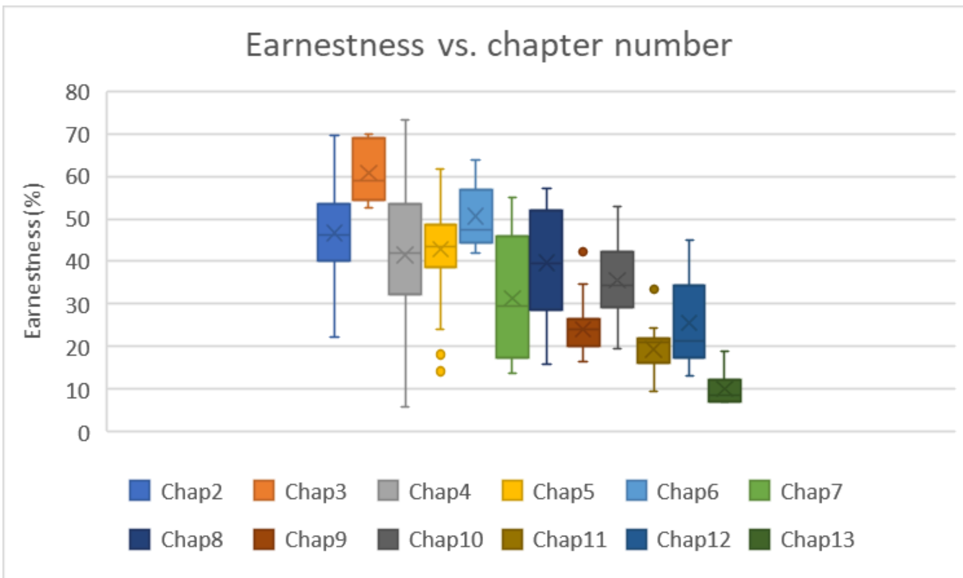


Figure 3: Boxplot of earnestness vs. chapter number (from chap. 2 (left) to chap. 13 (right)).

The one-way ANOVA p-value for this experiment is -4.44×10^{-16}, indicating statistically significant difference in student earnestness across chapters.

Figure 4 shows the mean and standard deviation of earnestness versus chapter number.

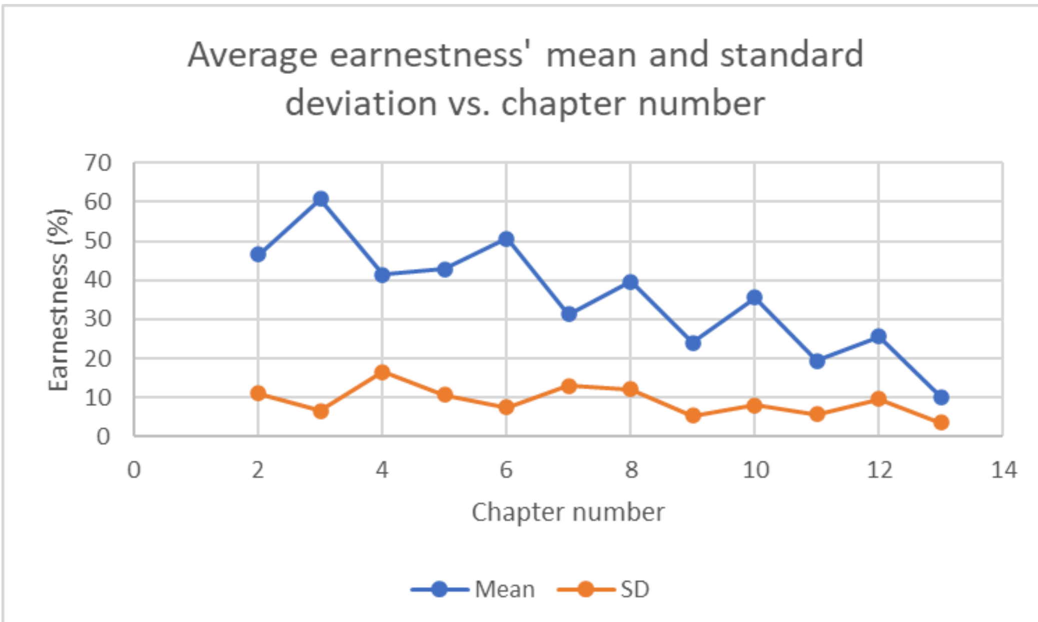


Figure 4: Earnestness mean and standard deviation (SD) versus chapter number.

The earnestness mean regression line is y = -3.434 x + 61.413 and has an R-squared value of 0.748. The earnestness standard deviation regression line is y = -0.539 x + 13.184 and has an R-squared value of 0.269. The negative slope in both regression lines shows that both the mean and standard deviation decrease as chapter numbers increase, with mean decreasing more prominently.

The data suggests that the average earnestness decreases as students progress through the chapters. The resulting drop in earnestness as chapter number increases agrees with findings of other studies as observed by [28] in circuit analysis, by [29] in introduction to programming in C++, and by [30] in introduction to programming in Java, Python, and C++. The drop in earnestness may in part be due to topics getting more difficult or containing more cumbersome calculations in increasing order of chapter numbers, or dependency of student retention of prior learned material needed to understand and learn later topics. The results of a study [31] focused on student effort and performance over the semester for an intermediate macroeconomics course suggest that student efforts decrease over a semester as students respond to higher midterm scores by reducing the number of hours they allocate to studying for the course.

Earnestness versus chapters' section number

To determine if earnestness changed within a chapter, the earnestness scores from chapters 2-13 of the control systems engineering textbook were pooled based solely on the section number for sections that contained short answer questions. So, the earnestness scores from section one in each chapter (excluding chapter one), the earnestness scores from section two in each chapter (excluding chapter one), and so on, were pooled separately for analysis.

Figure 5 shows the boxplot of earnestness versus section number, with section 1 from left to section 12 on the right. Note that there are fewer chapters that have high numbers of sections, and that there is a marked drop in earnestness for sections 10 to 12 compared to lower numbered sections. Of chapters 2-13, ten chapters have earnestness data available for sections numbered up to 5-8, while three chapters have earnestness data for sections numbered up to 10-12.

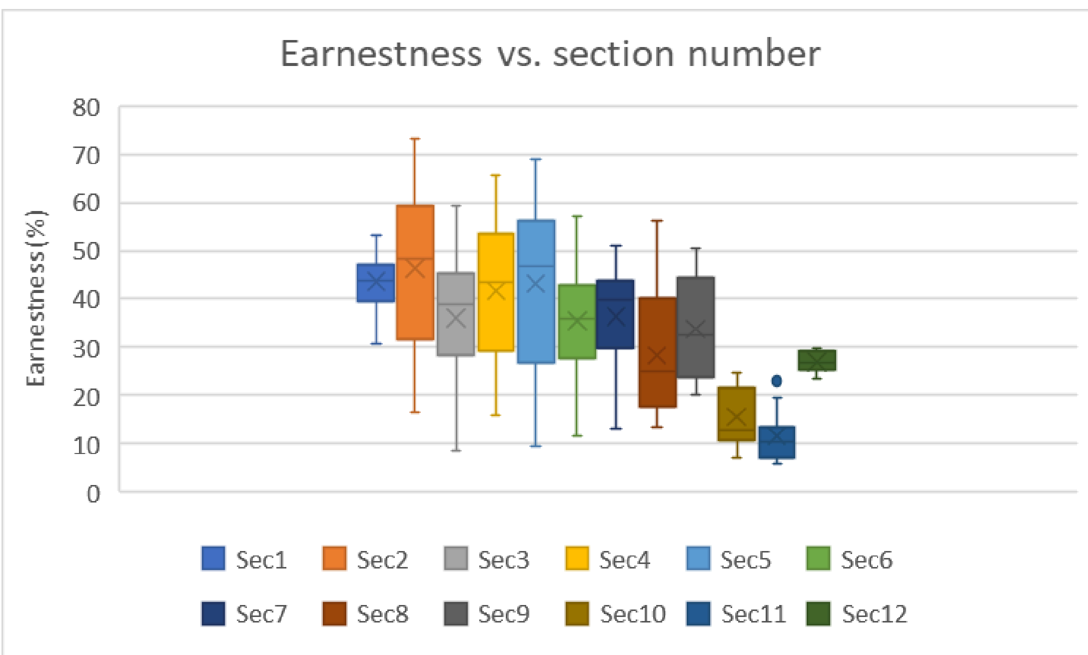


Figure 5: Boxplot of earnestness vs. section number (from sec. 1 (left) to sec. 12 (right)).

The one-way ANOVA p-value for the data in Figure 5 is 2.22E-16, indicating a statistically significant difference in earnestness for various chapter sections.

Figure 6 shows the mean and standard deviation of earnestness versus section numbers. A decrease in mean earnestness correlates well with increasing section, R-squared = 0.694. The linear regression for the mean earnestness versus section number is y = -2.527 x + 49.660 and has an R-squared value of 0.694. Also, the linear regression for the standard deviation earnestness versus section number is y = -0.773 x + 14.900 and has an R-squared value of 0.337. The regression lines show clearly that mean and standard deviation both decrease as the section number increases, especially for the mean, evident from a more negative regression line slope.

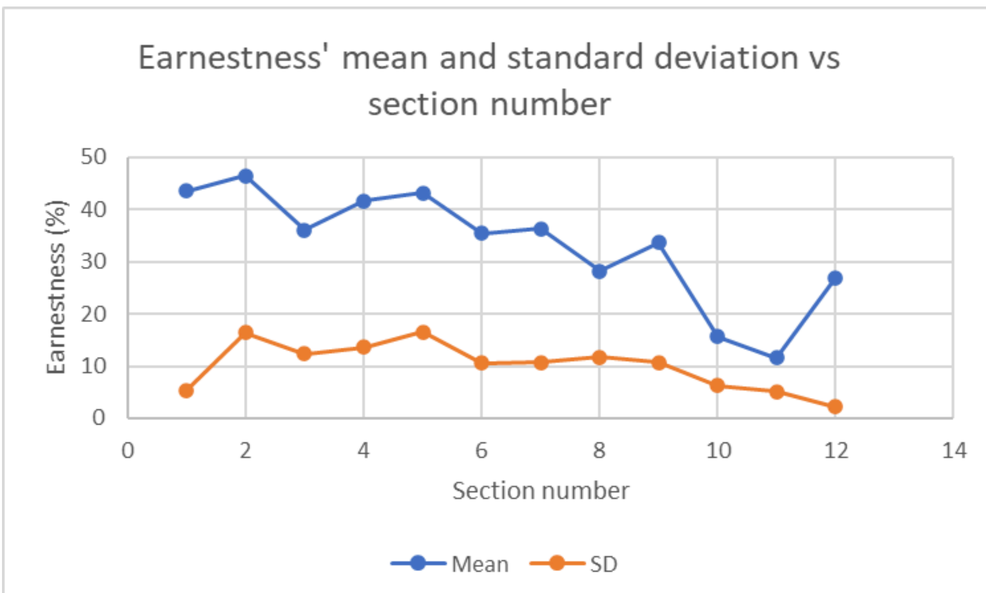


Figure 6: Earnestness mean and standard deviation (SD) versus section number.

The data shows that there is a decrease in earnestness as section numbers increase. This effect is more pronounced for higher section numbers.

Results of this study agree with results from a study of a circuit analysis zyBook [28] that found a change in earnestness within chapters as students progressed through sections of the chapter. Causation for the correlation in average student earnestness related to section number has not been investigated. The authors have speculated several possible reasons, such as student fatigue, instructors' emphasis on coverage of those later sections, student willingness or ability to invest time for study, and more detailed or higher-level of difficulty of the content in later sections.

Earnestness versus class size

To evaluate the effect of class size on earnestness, the control systems engineering class sizes were pooled from all 68 institutions into groups of ten, with group 1 from 1 to 10 students, group 2 from 11 to 20 students, and so on. The mean and standard deviations of earnestness of groups 1 to group 8 (1 to 10 students up to 71 to 80 students per class) are shown in Figure 7. The linear regression line for the data mean shown in Figure 7 is y = 0.881 x + 47.641 and has an R-squared value of 0.2228, indicating a weak correlation between mean earnestness versus class size. The linear regression line for the data standard deviation shown in Figure 7 is y = 0.072 x + 35.646 and has R-squared value of 0.0355, indicating the evidence of very little difference in earnestness standard deviation versus class size.

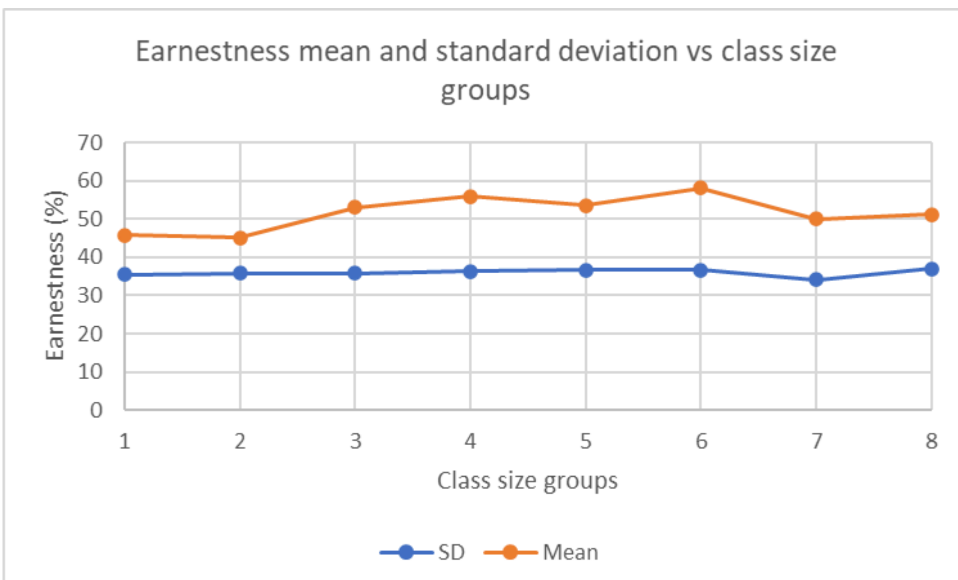


Figure 7: Earnestness mean and standard deviation (SD) vs. class size groups

Data was also available for five classes larger than 80 students, including courses with 92, 163, 165, 231, and 254 students. The mean and standard deviation for these classes are shown in Figure 8. The linear regression line for the data mean shown in Figure 8 is y = -0.154 x + 73.126 and has an R-squared value of 0.856, indicating the evidence of a decrease in earnestness mean versus class size. The linear regression line for the data standard deviation shown in Figure 8 is y

= -0.021 x + 35.633.717 and has an R-squared value of 0.131, indicating a very slight change (decrease) in earnestness standard deviation for large class sizes. The low R-squared indicates a poor linear fit, suggesting we can't make a strong claim about change in standard deviation versus class size. Note that the earnestness behavior is different for class sizes up to 80 students and for class sizes of 92 students and higher evident by a slight rise in mean earnestness for smaller class sizes versus a decrease for larger class sizes. Larger class sizes show more sensitivity evident by a steeper slope in the regression line.

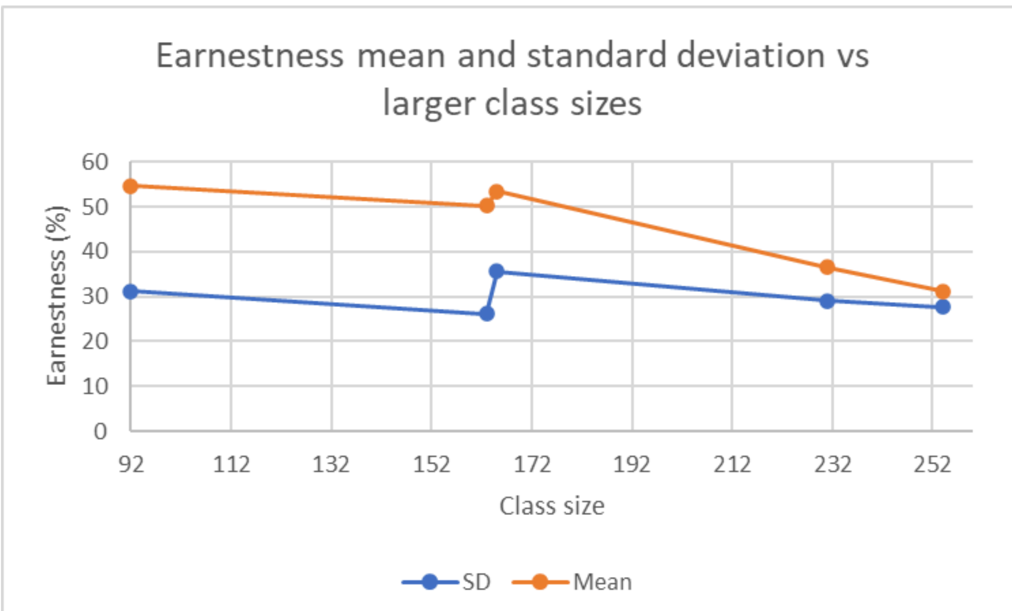


Figure 8: Earnestness mean and standard deviation (SD) vs. class sizes of 92 (group 11), 163 (group 12), 165 (group 13), 231 (group 14), and 254 (group 15) students.

Before completing these analyses, the authors had anticipated that class size might not affect student earnestness in the *Control Systems Engineering* zyBook. Earlier research with a circuit analysis zyBook found that class size had no impact on average student earnestness [28]. But results from other earlier research about the impact of class size on student outcomes were mixed. Like [28], some studies found that class size had no impact on overall student grades [32], [33], [34]. Other studies suggest that smaller classes are linked to stronger learning outcomes [35], [36], [37]. Because of the mixed results in earlier research, and because control systems engineering is a more advanced course than circuit analysis, we speculate that class size could possibly have a greater impact on student behavior in that different context. The results for the 68 control systems engineering courses found class size to have no impact on student outcomes for class size groups from 1 to 80 students, but there was a slight impact for class groups larger than 80. Average student earnestness decreased slightly as class sizes increased for class groups larger than 80. It is interesting to note that in the circuit analysis study that found no significant difference in average earnestness based on class size, only one of the 25 institutions had a class size greater than 80 (it was 99). Also, the circuit analysis study did find a larger variance in earnestness in larger class sizes compared to smaller class sizes [28].

Earnestness versus institution

A sample of 16 of the 68 institutions (a mix of Carnegie class R1, R2, and Other universities) was randomly chosen within each Carnegie class (3 "R1", 5 "R2", and 8 "Other") to be analyzed for average student earnestness related to their institution, to determine if there is any difference in average student earnestness between institutions. Figure 9 shows the boxplot of earnestness for the 16 randomly selected institutions.

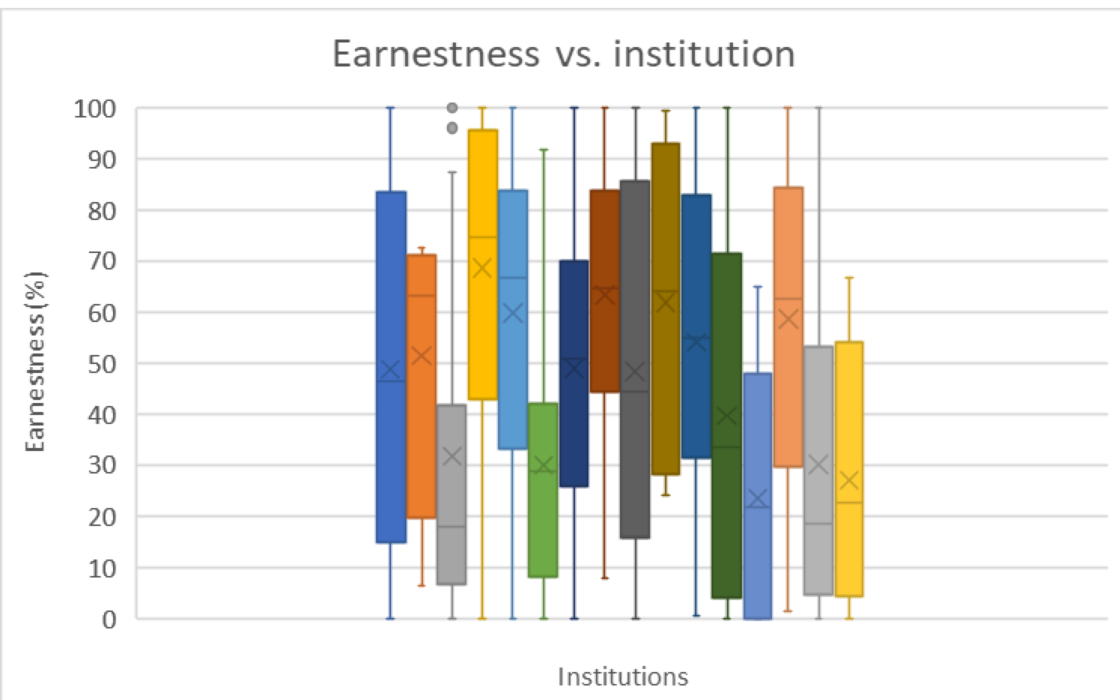


Figure 9: Boxplot for earnestness vs. institution for 16 institutions.

The one-way ANOVA analysis of the data in Figure 9 results in a p-value of 6.15E-8, indicating that the mean values of average student earnestness are very different across different institutions.

The correlation of average student earnestness with their institution is also evident when different institutions are grouped by class size, and then analyzed by institution within the class size group. For example, considering class sizes of 5 to 9, 10 to 14, 15 to 19 students and so on, each class size group showed strong evidence of the individual institutions having a correlation with earnestness. This data indicates that there is some aspect of the individual institutions that is not class size that is impacting student earnestness, since the average student earnestness varies so greatly across institutions within class size groupings. Of the factors evaluated for correlation with student earnestness, the students' institution has the second highest correlation.

For brevity, only one example is presented. There were nine institutions in the dataset with 25 to 29 students in their class. Figure 10 shows the boxplot of earnestness for these nine institutions. There is an obvious difference in earnestness relative to the institution within the class size grouping of 25 to 29 students.

Figure 10: Boxplot of earnestness vs. institution for class size groups of 25 to 29 students.

In this study we did not thoroughly investigate why student earnestness differs among institutions. Perhaps there was a difference in implementation among the analyzed institutions, such as assessments for the same topics spread across multiple assignments for more spaced practice. (Spaced practice has been demonstrated to result in better performance results than massed practice [10], [19].) Perhaps the nature of the student demographic differs. Perhaps the calendar of the institutions differs (e.g. quarter calendar vs. semester calendar). We hope to pursue these avenues of inquiry in future research. One characteristic of the institutions that has been investigated is the institutions' Carnegie classification.

Earnestness versus section institutions' Carnegie classification

Of the 68 institutions included in this study, 59 were able to be categorized by their Carnegie classifications and were pooled in groups based on their classifications into 12 R1, 18 R2, and 29 "Other". "Other" represented categories of not R1 or R2, and international institutions.
Figure 11 shows the boxplot of earnestness versus institutions' Carnegie classification. The mean earnestness scores were 45.73, 44.98, and 54.29 for classification of R1, R2, and Other,

respectively. The standard deviation for earnestness scores were 32.67, 36.31, and 35.51 for classification of R1, R2, and Other, respectively. These results indicate that there are no significant statistical differences between the R1 and R2 classified institutions, however, there is an increase of almost ten points in the mean earnestness for the Other category, which is statistically significant.

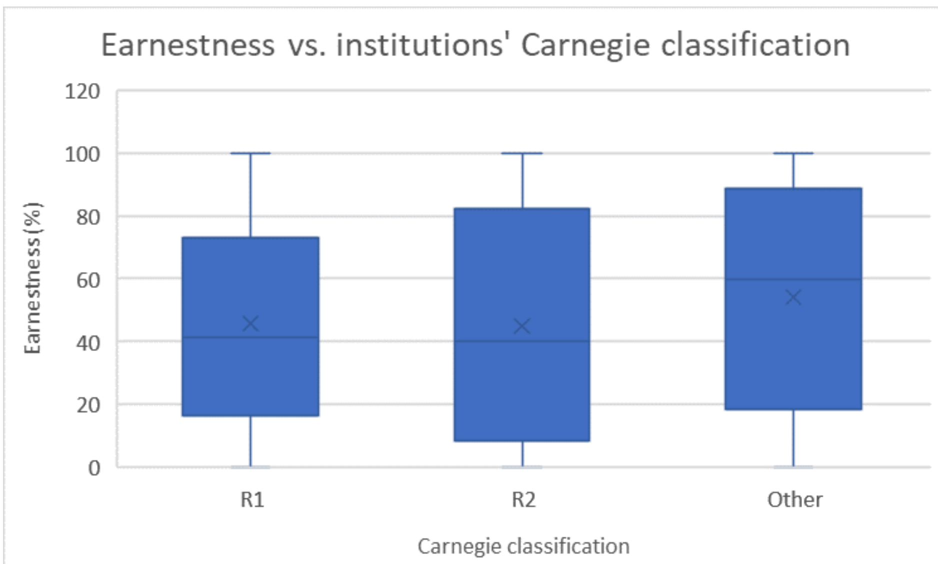


Figure 11: Boxplot of earnestness vs. institutions' Carnegie classification R1, R2, and Other.

Earnestness versus question difficulty

To inform analysis of the questions related to difficulty level, the difficulty of each Short Answer question set was rated based on the rubric shown in Table 4. The rubric defines difficulty based on the complexity and amount of direct or indirect use of concepts, and the number and complexity of math operations. Many students have anxiety related to math [38], and math continues to be a barrier for students advancing in STEM [39], [40]. The difficulty rating of each question set is based on the most difficult question in the set:

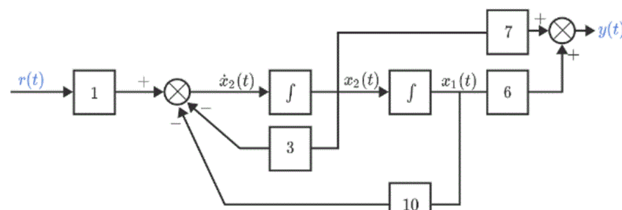
Table 4: Rubric for categorization of difficulty levels.

Description	**Example**

Conceptual: Straightforward, often no calculation needed. May require observing a graph, equation, or description in the question.	1) A second order system has ____ poles. Ex: 3 Check Show answer 2) A stable second-order system can have ____ different types of step responses. Ex: 3 Check Show answer	**Answer** 2 The system's order is the number of poles, so a se order system has two poles. **Answer** 4 The four responses: overdamped, underdamped, undamped, or critically-damped.
Easy: Requires calculations using one equation, or one simple concept and a couple of equations, or applying the correct point from a graph. Minimal indirect use of concepts/ cumbersome calculations.	What should replace B in the equations below? 1) Laplace transform $\mathscr{L}[Ae^{-at}u(t)] = \int_B^{\infty} Ae^{-at}e^{-st}dt$ Ex: 1 Check Show answer 2) $\int_{0-}^{\infty} Ae^{-at}e^{-st}dt = \int_{0-}^{\infty} Ae^{Bt}dt$ Ex: -(2s-a) Check Show answer 3) $\int_{0-}^{\infty} Ae^{-(s+a)t}dt = \frac{Ae^{-(s+a)t}}{-(s+a)}\Big\|_{t=0}^{\infty} = \frac{A}{B}$ Ex: 3s+a Check Show answer	**Answer** 0- $\mathscr{L}[Ae^{-at}u(t)] = \int_{0-}^{\infty} Ae^{-at}e^{-st}dt$ This is by definition of the Laplace transform. **Answer** -(a+s) $\int_{0-}^{\infty} Ae^{-at}e^{-st}dt = \int_{0-}^{\infty} Ae^{-(s+a)t}dt$ **Answers** s+a or a+s or (s+a) or (a+s) $\int_{0-}^{\infty} Ae^{-(s+a)t}dt = \frac{Ae^{-(s+a)t}}{-(s+a)}\Big\|_{t=0}^{\infty} = \frac{A}{s+a}$

Medium: Requires juxtaposing two concepts, or equivalent forms, and building one form from the other. May need calculations from two to four formulas used in proper order. Average indirect use of concepts/ cumbersome calculations.

The block diagram below implements state equations with matrix values E, F, G, H, N, and O to be determined. Readin diagram from right to left, each integrator yields a state equation such as $\dot{x}_1 = x_2$. The left-side summation circle indicate long state equation for $\dot{x}_2$.



$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} E & F \\ G & H \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} r$$

$$y = \begin{bmatrix} N & O \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

1) The system contains how many state variables?

Ex: 1

Check Show answer

Answer

2

From the state vector $\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$, the system contains t state variables. In the block diagram, the integrator outputs are state variables.

2) The upper-left coefficient of the system matrix $E =$ ____.

Ex: 1

Check Show answer

Answer

0

The second integrator shows $x_1 = \int x_2$, so $\dot{x}_1 =$ From the matrix, $\dot{x}_1 = Ex_1 + Fx_2$, so $E = 0$.

Hard: Requires several steps including calculating relevant formulas in correct order and/or looking up information from one or more graphs. Formula calculations and graph lookups may be interspersed. Greater than average indirect use of concepts/ cumbersome calculations.

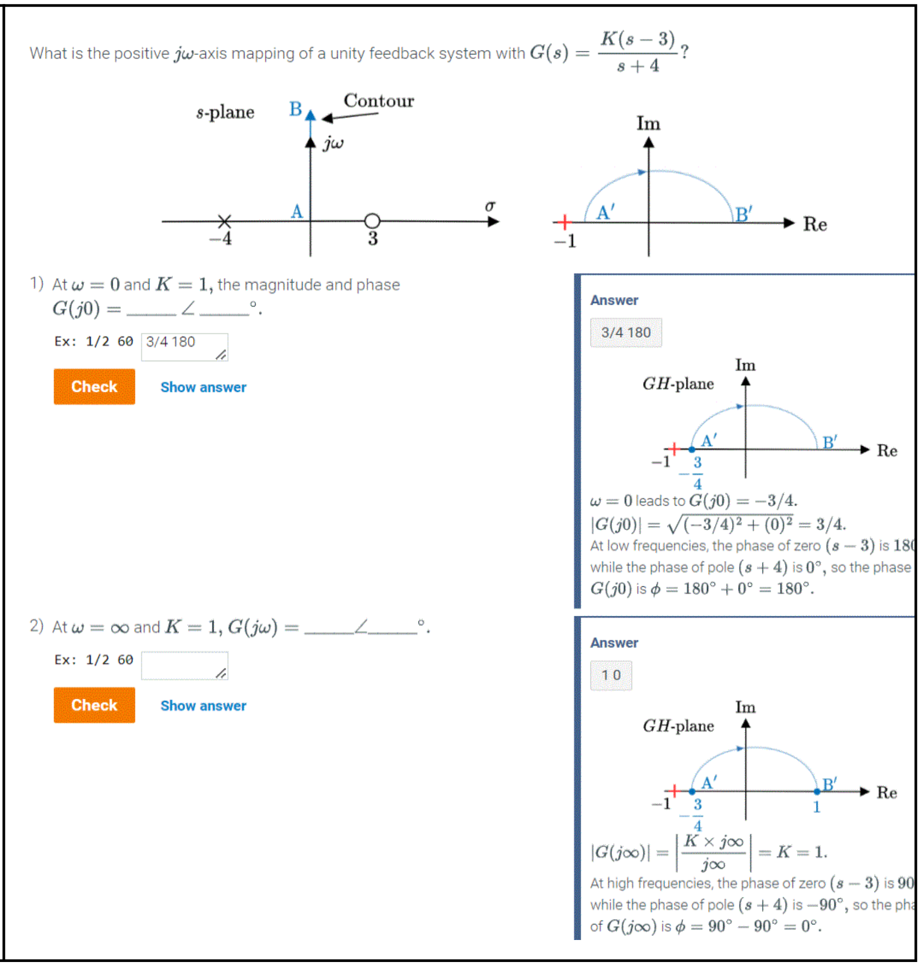


Figure 12 shows the boxplot for earnestness versus difficulty level. Note that only one question was categorized as "Conceptual" within the questions evaluated for earnest response for this study. Hence the presentation of difficulty level Conceptual in the boxplot as a line. There were additional Conceptual level questions in the online interactive control systems engineering textbook, but they were different question types (such as Multiple Choice) rather than the Short Answer question type evaluated for earnest response for this study.

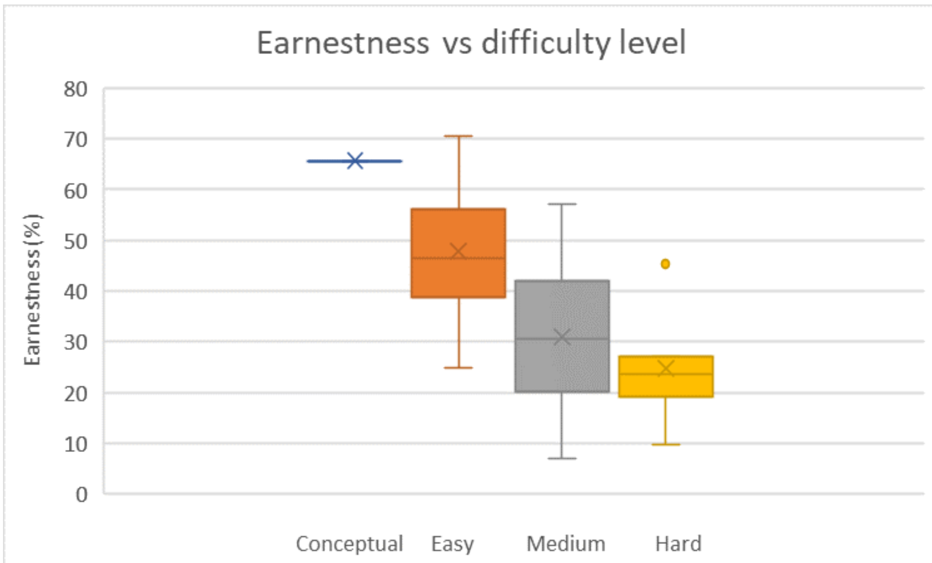


Figure 12: Boxplot of earnestness vs. difficulty level (Conceptual (left) to Hard (right)).

The one-way ANOVA analysis of the data shown in Figure 12 results in a p-value of 0.0004, indicating a strong correlation of question difficulty level with student earnestness. The mean of earnestness versus difficulty level results in the linear regression line y = -13.964 x + 77.166 and has an R-squared = 0.962 showing a strong decrease in mean earnestness as a function of difficulty level.

Question difficulty level is the factor observed to have the strongest correlation with student earnestness, with a sharp decrease in earnestness for each level of difficulty increase. The researchers in [28] and [29] also observed a correlation between a reduction in average student earnestness and greater question difficulty, though for [29] the measure of difficulty was designed differently.

The reduced student earnestness in answering more difficult practice questions has important implications to content development. Considering research has demonstrated that retrieval through answering questions results in greater retention compared to simply reading, one must also consider how content developers might influence increased student earnestness when practicing more difficult questions.

Limitations

The size of the data sets analyzed were dependent on students choosing to interact with the questions, with their interactions recorded by clicks in the platform. The data from the 68 institutions was obtained from the institutions' usage of a shared product and platform, but that usage was not coordinated in any way across institutions or instructors. Different instructors choose to assign different chapters and sections, and student interactions with questions have been observed to range from 0-3% when a section or chapter is not assigned in the platform. Consequently, the majority of students interacted only with questions in sections and chapters that were assigned to them. So, for example, the number of student responses available for analysis in one chapter compared to another chapter varies depending on how many instructors assigned each chapter. As such, the size of the data sets was not consistent across all factors evaluated, but the size of the data sets for all factors was sufficient for the results of the analyses of average student earnestness to be statistically significant.

Another limitation is that the analysis of student earnestness related to progression within chapters was analyzed solely based on section number. Additional analysis could be performed based on the number of subsections in chapters and sections. Such analysis may further inform why higher earnestness is demonstrated in some section groupings compared to others shown in Figure 5.

Conclusion

This study analyzed students' average earnestness in responding to short answer questions in the *Control Systems Engineering* zyBook when the answer was easily available. The correlation of student earnestness with a number of factors was analyzed. Evaluation of the results within the control systems engineering courses revealed a strong correlation between student earnestness and factors like question difficulty, but weak to no correlation with factors like class size. These aspects of the results were also consistent with what was observed with circuit analysis and computer science zyBooks.

The results of this study indicate that a majority of students using the *Control Systems Engineering* zyBook achieve 28%-68% or better earnestness scores for a majority of the chapters when the answer is easily available. The chapter number has an impact on average student earnestness: earnestness is highest in the earliest chapters. This suggests that student earnestness is highest at the beginning of the course. The change in student earnestness may be attributed to student fatigue as the term progresses, or to a deliberate shift on the part of students to achieve a level of equilibrium that can be maintained across their course load, and/or optimizing workload vs desired grade. The theme of student earnestness declining is repeated as students progress through sections within a chapter. Within a chapter, earnestness is higher for earlier sections and lower for later sections. The authors speculate this may be due to student fatigue, or more detailed or higher-level of difficulty of the content in later sections, or lack of retention of prior material for topics that build on earlier topics, among other causes.

Question difficulty level was the factor found to have the greatest correlation with average student earnestness. Average student earnestness was found to decrease sharply as question difficulty level increased. Which begs the question, with awareness of the research demonstrating retrieval through answering questions to result in greater retention compared to reading, how can content developers influence greater student earnestness when practicing more difficult questions?

Students' institution was the factor with the second highest correlation observed to student earnestness. Institutions' Carnegie classification seems to be related to this, as institutions with an Other classification (not R1 or R2) have a statistically significant higher mean earnestness than the R1 and R2 institutions. Further investigation is planned into what other characteristics may contribute to the causation of institution correlation to student earnestness. The smallest correlation in the factors evaluated was observed between average earnestness and class size, but this correlation was not apparent until class size groups exceeded 80 students. For class size groups exceeding 80 students, student earnestness decreased slightly as class sizes increased.

Future investigations are planned into student earnestness related to variations in level of difficulty of questions within a set, the type of feedback provided to students, as well as the length of time required to complete the questions. We are also seeking instructor partners to investigate whether any correlation exists between student earnestness in zyBooks and student academic performance. The goal is to provide insight into the relationship between student engagement and achievement, and student background and demographic factors.

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