Student Engagement with Interactive Engineering Textbook Reading Assignments When Tied to the Grade

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Abstract

Engineering courses have seen a rise in the usage of online textbooks, especially in response to the COVID-19 pandemic and the need for classes to be remote. Some of these online textbooks contain learning questions, video media, animations, simulations, 3D tools, and other interactive elements. The goal for these interactive elements is for students to engage through reading, answering questions, watching videos, stepping through animations, or otherwise participating with the interactive content. Despite the availability of such interactivity, student engagement is not a guarantee. Due to time constraints and other pressures, students may opt for racing through the textbook or skipping the interactive elements entirely, rather than earnestly interacting with the material. In response, some instructors have tried to motivate reading by assigning the completion of reading assignments as a percentage of the final course grade. This paper investigates how student textbook engagement is affected when reading assignments are tied to the final course grade.

This paper uses data from online interactive engineering textbooks containing short answer, matching, and multiple-choice questions, along with animations as assigned activities. The animations show key conceptual information and are viewed in a sequential step order. All steps must be viewed in order to receive credit. For this paper, we measure student engagement through activity completion percentage. We describe the various components of interactive engineering textbooks, outline a definition of engagement, and summarize overall textbook engagement data. Across three engineering textbooks (Callister's Materials Science and Engineering: An Introduction, Nise's Control Systems Engineering, and Irwin's Basic Engineering Circuit Analysis), we confirm a significant positive correlation between student engagement and the percentage of final course grade awarded for completion of assigned activities. Assigning any percentage at all corresponds to over a 35% increase in content completion, and the higher the assigned percentage, the greater the completion increase. These results strongly suggest that instructors should assign course credit for completion of interactive textbook material if they want students to read and engage.

Introduction

Research over the last four decades shows that a majority of students ignore textbook readings [1]-[7]. For example, over 72,000 first-year students were surveyed between 2018-2022 and asked how much of their time is spent on assigned reading when preparing for class in a typical 7-day week. 45-49% of students responded that they spent less than half of their time on assigned reading [3]. The research also indicates that lower rates of textbook reading corresponds to lower course grades [2], supporting the importance of reading for students' learning and achievement. Furthermore, students know that reading is important and that it impacts their grade [7]. Thus, strategies that motivate students to actively read textbooks can and should be implemented to increase engagement and as a result, improve students' learning and course performance.

Online, interactive textbooks allow students to interact with dynamic content, unlike traditional print textbooks that are limited by static content. An interactive textbook can respond to a student's input and show dynamic content. Several works have explored different multimedia tools to use in interactive engineering textbooks in an effort to engage student learning [8]-[10]. While low reading rates are also a challenge for online interactive textbooks, textbooks that adopt a learn-by-doing approach create a form of active learning for students in engineering courses [11]-[13]. For example, [11] shows that students are more engaged with the interactive textbook in both an introductory control systems and a materials science engineering course.

While an interactive textbook promotes active learning, whether or not students take advantage of this interactivity determines how effective such textbooks will be. One factor that can determine student engagement with the interactive content is instructor assignment of points toward the student grades for completion of the reading. Some instructors have successfully increased student reading engagement by assigning quizzes about the readings to incentivize students to read [14]-[16]. In a study of 159 psychology students, mastery-based online quizzes required before the readings were to be discussed in class led to both better exam scores and overall course performance [14]. Performance on exam questions was especially improved when those questions came from a chapter that had been covered on a quiz (compared to questions from chapters without corresponding quizzes). Other instructors find success using reading questions to be completed as students complete the reading, rather than quizzes given afterward [17]-[18].

Interactive online textbooks make it easy to assign credit for reading and completing active learning activities. While such textbooks can track and report completion, it is up to the discretion of instructors how to make use of that information. Is it enough to include such activities and show students their progress while navigating through the text? Is assigning some course credit for completion of content more effective at encouraging students to engage? Furthermore, does the amount of course credit assigned for completion have an impact on how much students will engage? This paper explores the effectiveness of tying a percentage of students' grade to interactive reading and investigates whether the amount of grade percentage tied to the reading has an effect.

Materials

The textbooks in this paper utilize reading activities in the form of animations and learning questions as the basis for the interactivity. This allows students to engage with the textbook instead of passively reading static text with figures. Both animations and learning questions create an active reading environment that checks a student's understanding of the chapter or section content, while rewarding students points for completion (i.e., gamification).

In response to the declining student engagement with traditional print textbooks, interactivity was added to three engineering textbooks in the subjects of control systems, materials science and engineering, and circuit analysis. While the text from the original print books remains mostly unchanged, interactivity was added in the form of animations and learning questions. The animations that were added to the now interactive textbooks are composed of dynamic images, equations, text, and other interactive visual elements. The learning questions that were added are in multiple formats including multiple choice, short answer, and matching. These animations and learning questions can be assigned to students and the student completion of the reading activities can be easily tracked. The student completion data can be compared to the survey data about textbook reading but can also be used to show a correlation between participation in the reading activities and the grade in the class [19].

Control Systems Textbook

The Control Systems Engineering textbook by Nise that was converted into the online interactive format was previously available both in print and digitally to users. The new interactive format includes appendices, solutions to exercises, as well as the interactive reading questions and animations. The interactive animations in the control systems textbook were 5-8 step animations that visually demonstrated the concepts discussed in the text or demonstrated the procedure to solve a problem. Every step in the animation includes a concise caption describing what is occurring in the animation. For the control systems textbook, most questions were in the short answer format that walks students through a lengthy problem. With short answer questions, the student has to type in a solution in the space provided. Students are provided with a hint after an incorrect answer and a full explanation is shown either after the correct answer is input or when a student clicks the "show answer" button. Students can attempt to answer the question as many times as they choose without showing the answer but must input the correct answer to receive credit even after the solution has been shown.

Materials Science and Engineering Textbook

Callister's Materials Science and Engineering textbook is well established and widely used as both a reference book and teaching text for introductory materials science and engineering courses. The animations in the materials science and engineering textbook included conversions of static figures to animations when the figure did not sufficiently describe a process, conversions of all example problems and design examples, and other animations that add visuals where there was only text. The interactive reading questions in the materials science and engineering book are primarily in the multiple choice or matching formats, with a smaller number of short answer questions when necessary. Each multiple-choice question was designed to help guide a learner to fully understand key concepts, with choices that specifically target misconceptions. After choosing one of the options, a student is shown why the selected answer is correct or incorrect. Matching questions were generally used to help students understand key terms in a section or to understand the meanings of key symbols in equations.

Circuit Analysis Textbook

The Basic Engineering Circuit Analysis textbook by Irwin is primarily used for introductory-level undergraduate circuit analysis courses. The text is used for courses intended for both Electrical and Computer Engineering majors, and other Engineering discipline majors. Similar to the control systems textbook, the majority of activities in the circuit analysis textbook were short answer questions that focused on walking students through the steps of computing various analyses around circuits.

Methodology

An end-of-term survey was sent to instructors who had taught from one of the three textbooks mentioned above. The survey asked instructors what percentage toward students' final grades was awarded for completing the reading activities in the online textbook. Instructors could respond with one of the following ranges: 0%, 1–5%, 6–10%, 11–15%, or 15+%. For each textbook, we identified survey respondents who taught similar sections of the textbook, to enable fair comparison of completion data among those courses.

For the Materials Science text, seven instructors’ courses were selected: two who assigned 0% for completion, one who assigned 1–5%, three who assigned 6–10%, and one who assigned 11–15%. In total, there were 85 students who were assigned 0% credit for participation, 49 who were assigned 1–5%, 84 who were assigned 6–10%, and 39 who were assigned 11–15%. We identified sections of the text that were used in each of these instructor's courses, equaling 30 sections in total.

For the Control Systems text, seven instructors’ courses were selected: one who assigned 0% for completion, two who assigned 1–5%, two who assigned 6–10%, and two who assigned 15+%. In total, there were 17 students who were assigned 0% credit for participation, 79 who were assigned 1–5%, 58 who were assigned 6–10%, and 59 who were assigned 15+%. We identified sections of the text that were used in each of these instructor's courses, equaling 16 sections in total.

For the Circuit Analysis text, four instructors' courses were selected: one who assigned 0% for completion, and three who assigned 6–10%. In total, there were 26 students who were assigned 0% credit for participation, and 91 students who were assigned 6–10%. We identified sections of the text that were used in each of these instructor's courses, equaling 10 sections in total.

Table 1 shows the total number of animations and question sets in the common sections of each textbook as well as the average number of steps in each animation and the average number of questions per set. A table showing the specific topics covered by the sections used in the study and the number of reading activities of each type included in each section is included in Appendix A.

Subject	Animations	Question Sets
Materials Science	39 animations with an average of 3.8 steps per animation	43 question sets with an average of 3.6 learning questions per set
Control Systems	41 animations with an average of 4 steps per animation	55 question sets with an average of 3.3 learning questions per set
Circuit Analysis	14 animations with an average of 6.9 steps per animation	35 question sets with an average of 4.1 learning questions per set

Table 1: Number of reading activities of each type in the common sections of each textbook

We calculated the percent completion for each (anonymized) student in the identified courses. Percent completion was defined as the proportion of reading activities in the identified sections that the student completed. For each of the three textbooks, the average completion rates were compared across the different ranges of percentage of points assigned for reading activity completion. One-way ANOVAs were computed for each of the three texts, and Tukey multiple comparisons of means were calculated for pairwise comparisons.

Results

For the Materials Science students, a significant effect of points assigned was observed ($F(3,239) = 50.33$, $p < 2e\text{-}16$, $\eta^2 = .39$). The averages for each course are shown in Figure 1. Paired comparison means, confidence intervals, and p-values are shown in Table 2. All between-group comparisons showed a significant difference, except for that between 1–5% and 6–10%.

Compared to courses assigned 0%, those assigned 1–5% had a 36% higher completion rate, those assigned 6–10% had a 40% higher completion rate, and those assigned 11–15% had a 54% higher completion rate.

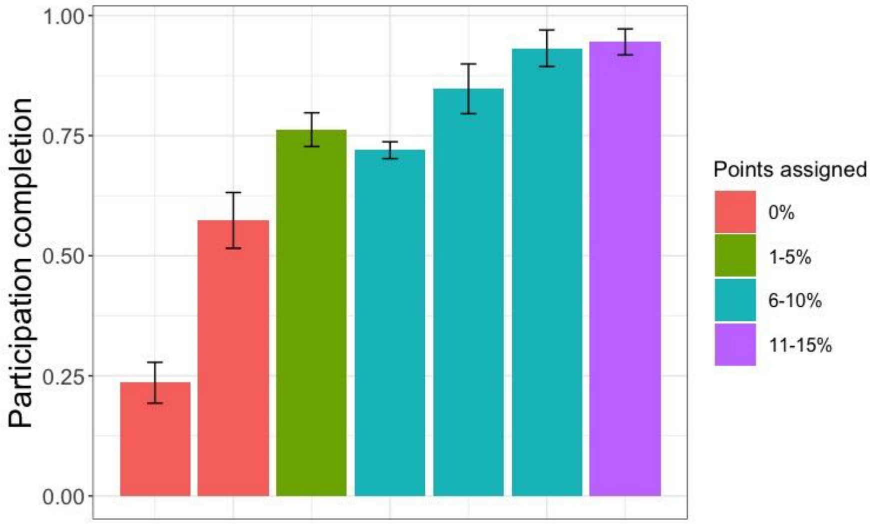

Figure 1: Means and standard deviations for courses using the Material Science textbook.

Paired comparison	Lower CI	Upper CI	Mean Difference	P-adjusted
0% - 1–5%	.24	.48	.36	.000***
0% - 6–10%	.29	.50	.40	.000***
0% - 11–15%	.41	.67	.54	.000***
1–5% - 6–10%	-.07	.16	.04	.810
1–5% - 11–15%	.04	.33	.18	.006***
6–10% - 11–15%	.01	.27	.14	.025***

Table 2: Materials Science paired comparisons

For the Control Systems students, a significant effect of points assigned was observed ($F(3,200) = 24.69$, $p < 1.24e\text{-}13$, $\eta 2 = .27$). The averages for each course are shown in Figure 2. Paired comparison means, confidence intervals, and p-values are shown in Table 3. All between-group comparisons showed a significant difference, except for that between 6–10% and 15+%. Compared to courses assigned 0%, those assigned 1–5% had a 37% higher completion rate, those assigned 6–10% had a 50% higher completion rate, and those assigned 15+% had a 58% higher completion rate.

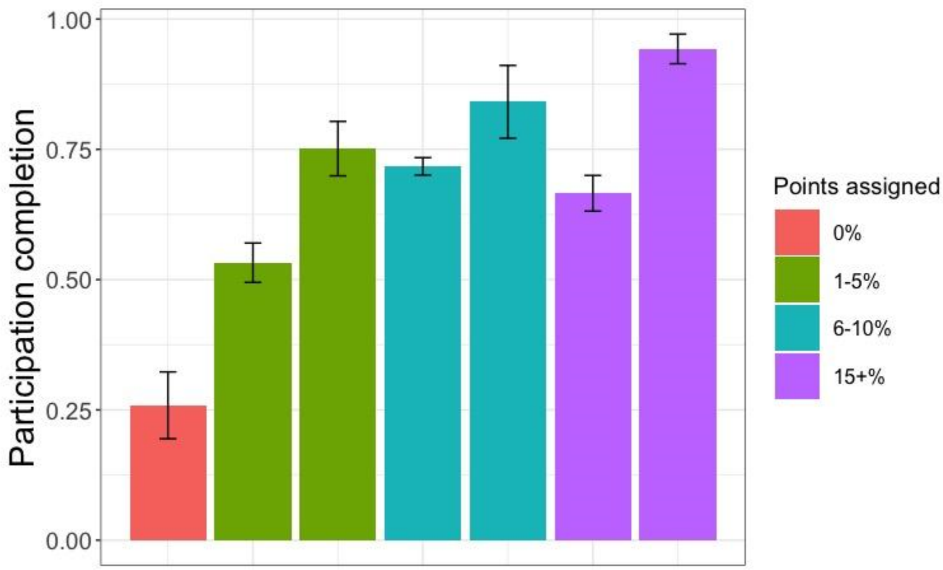

Figure 2: Means and standard deviations for courses using the Control Systems textbook.

Paired comparison	Upper CI	Lower CI	Mean Difference	P-adjusted
0% - 1–5%	.18	.55	.37	.000***
0% - 6–10%	.31	.69	.50	.000***
0% - 15+%	.58	.39	.58	.000***
1–5% - 6–10%	.02	.24	.13	.013*
1–5% - 15+%	.10	.32	.21	.000***
6–10% - 15+%	-.03	.20	.08	.236

Table 3: Control Systems paired comparisons

For the Circuit Analysis students, a significant effect of points assigned was observed ($F(1,112) = 4.235$, $p < 2e\text{-}16$, $\eta 2 = .52$). The averages for each course are shown in Figure 3. There are no additional pairwise comparisons for Circuit Analysis, as only two point ranges (0% and 6–10%) were present in the data. Compared to courses assigned 0%, those assigned 6–10% had a 48% higher completion rate.

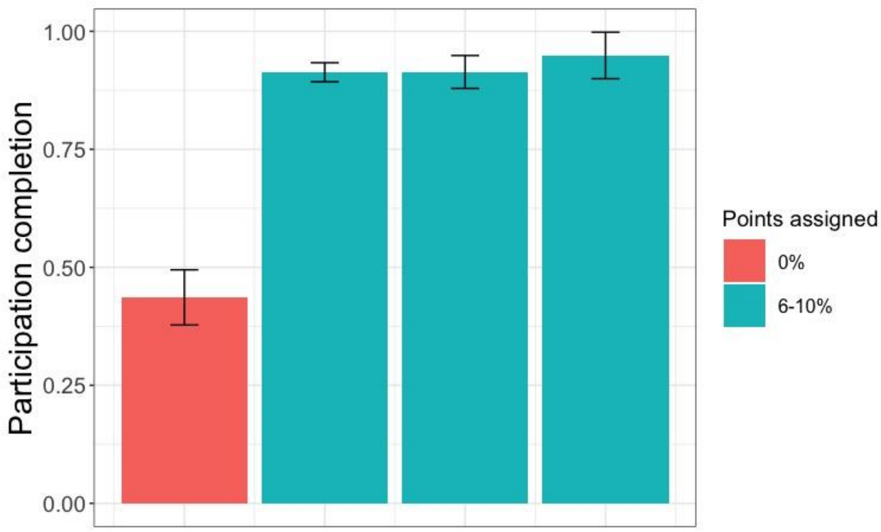

Figure 3: Means and standard deviations for courses using the Circuit Analysis textbook.

Discussion/Limitations

The results of this study, across 18 instructors and 587 students, show that there is a significant relationship between the amount of credit assigned for reading activities and the level of engagement demonstrated by students. As the percentage of credit assigned for completion of interactive elements increases, so does the completion of content by students. Across all observed subjects in this study, assigning any points at all corresponds to over a 35% increase in content completion. This finding has important implications for instructors looking to increase student engagement with interactive textbooks. By tying a portion of the final course grade to the completion of interactive elements, instructors may incentivize students to actively engage with the course material. However, there are some limitations to the study that should be acknowledged.

It is not possible to determine causality from this correlational data. It cannot be determined whether assigning more points leads to increased engagement, or if students who tend to receive more points are more likely to be engaged with the material for other reasons. For instance, perhaps the instructors in our study who tend to assign credit for participation also tend to engage in other helpful practices, or tend to have higher rapport with their students. Further experimental research is needed to establish causality.

Only engineering courses were evaluated in this study, and therefore the data may not be appropriate when considering other subjects. Additionally, the study only analyzed a subset of engineering books, so a more diverse sample would help determine whether this pattern is present across all engineering textbooks. Furthermore, only a subset of sections were analyzed within each text, as using content that was shared between a large enough sample of courses was important for robustness. The content in the selected sections consists typically of early chapter content. Further research should investigate whether later sections of the text exhibit the same pattern dependent on point assignment.

Specific to the Circuit Analysis text is the limitation of only two levels of percentage points assigned (0% and 6-10%) by the participating instructors. Thus, while there is sufficient evidence that a higher grade percentage assigned results in more completion across the other two texts, the present data do not allow such comparison for Circuit Analysis.

Despite these limitations, this study provides some insight into the correlation between grade percentage for completion and student engagement with the text. Further research could be built on these findings to gain a deeper understanding of this correlation and of student textbook engagement itself.

Conclusions and Future work

This paper described an experimental study that investigated how student textbook engagement is affected when reading assignments are tied to the final course grade. Some instructors motivate students to read by assigning reading assignments as a percentage of the final course grade. Data was collected from 18 instructors and 587 students using three online interactive engineering textbooks containing animations and learning questions as assigned activities. The textbooks included introductory materials science and engineering, introductory control systems, and introductory circuit analysis. For all three textbooks, the results of this study showed a significant relationship between assigning credit for reading activities and a student's level of engagement. Students completed more of the reading activities as the amount of assigned credit increased for those activities.

However, it was noted that the correlation in the results does not indicate causality. The level of engagement could be due to other factors and not necessarily the direct result of the amount of points assigned for completing reading activities. Thus, more work is needed to determine the exact cause of the increased student engagement. A longitudinal study of the interactive reading activities could be conducted to evaluate whether time spent in completing reading activities for interactive textbooks in other subjects increases over time. The student completion data for the reading activities can also be compared to student grades to investigate potential correlation between completion of reading activities or time spent on reading activities and the students' grades in the course. Research has shown that students who complete more of the reading activities are more likely to achieve higher course grades in a material and energy balances textbook [19]. In particular, A/B students tended to complete 95-100% of the reading, while C/D/F students tended to complete 70-95%. However, the causal nature of this relationship has yet to be explored. Also, data from more engineering textbooks, other than the three considered in this paper, could be analyzed to produce a better understanding of student engagement for the engineering discipline.

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Appendix A

Title	Sections included in study	Types/Number of Reading Activities
Materials Science	Historical Perspective	1 Animation with 3 steps 1 Question set with 3 learning questions
Materials Science	Materials science and engineering	2 animations with 3-5 steps 2 question set with 6 learning questions
Materials Science	Why study materials science and engineering	2 animation with 5 steps 1 question set with 4 learning questions
Materials Science	Classification of materials	1 animation with 4 steps 1 question set with 4 learning questions
Materials Science	Advanced materials	1 animation with 4 steps 1 question set with 3 learning questions
Materials Science	Modern materials’ needs	1 animation with 3 steps 1 question set with 3 learning questions
Materials Science	Introduction to atomic structure	No animations or learning questions
Materials Science	Atomic structure: Fundamental concepts	2 animations with 4 steps each 2 question sets with 3-5 learning questions
Materials Science	Atomic bonding in solids: Bonding forces and energies	1 animation with 3 steps 1 question set with 4 learning questions
Materials Science	Atomic bonding in solids: Primary interatomic bonds	5 animations with 3-5 steps 5 question sets with 3-5 learning questions
Materials Science	Atomic bonding in solids: Secondary bonding or van der Waals bonding	2 animations with 3 steps each 4 question sets with 3 learning questions each
Materials Science	Atomic bonding in solids: Mixed bonding	1 animation with 3 steps 1 question set with 4 learning questions
Materials Science	Crystal structures: Fundamental concepts	No animations 1 question set with 3 learning questions
Materials	Crystal structures: Unit cells	1 animation with 3 steps

Science		1 question set with 3 learning questions
Materials Science	Crystal structures: Metallic crystal structures	5 animations with 3-4 steps 4 question sets with 3-4 learning questions
Materials Science	Crystal structures: Density computations	1 animation with 3 steps 1 question set with 5 steps
Materials Science	Crystal structures: Polymorphism and allotropy	1 animation with 3 steps 1 question set with 3 learning questions
Materials Science	Crystal structures: Crystal systems	No animations 1 question set with 3 learning questions
Materials Science	Crystalline and noncrystalline materials: Single crystals	No animations 1 question set with 3 learning questions
Materials Science	Crystalline and noncrystalline materials: Polycrystalline materials	1 animation with 4 steps 1 question set with 3 learning questions
Materials Science	Crystalline and noncrystalline materials: Noncrystalline solids	No animations 1 question set with 3 learning questions
Materials Science	Introduction: Phase Diagrams	No animations or question sets
Materials Science	Definitions and basic concepts: Solubility limit	1 animation with 3 steps 1 question set with 3 learning questions
Materials Science	Definitions and basic concepts: Phases	1 animation with 3 steps 1 question set with 3 learning questions
Materials Science	Definitions and basic concepts: Microstructure	No animations or question sets
Materials Science	Definitions and basic concepts: Phase equilibria	1 animation with 4 steps 1 question set with 4 learning questions
Materials Science	Definitions and basic concepts: One-component	1 animation with 7 steps 1 question set with 3 learning questions

	(or unary) phase diagrams	
Materials Science	Binary phase diagrams: Binary isomorphous systems	2 animations with 3-4 steps 1 question set with 4 learning questions
Materials Science	Binary phase diagrams: Interpretation of phase diagrams	3 animations with 4-7 steps 3 question sets with 3-5 learning questions
Materials Science	Binary phase diagrams: Development of microstructure in isomorphous alloys	2 animations with 5-6 steps 3 question sets with 3-4 learning questions
Control Systems	Laplace transform review	5 Animations with 5, 4, 7, 6, and 6 steps 7 Question Sets with 28 learning questions
Control Systems	Poles, zeros, and system response	3 Animations with 3, 2, and 8 steps 4 Question Sets with 12 learning questions
Control Systems	First-order systems	4 Animations with 6, 3, 4, and 4 steps 5 Question Sets with 13 learning questions
Control Systems	Second-order systems: introduction	4 Animations with 5, 7, 7, and 6 steps 5 Question Sets with 15 learning questions
Control Systems	The general second-order system	1 Animation with 6 steps 3 Question Sets with 7 learning questions
Control Systems	Underdamped second-order systems	5 Animations with 3, 3, 4, 5, and 4 steps 7 Question Sets with 29 learning questions
Control Systems	System response with additional poles	2 Animations each with 3 steps 2 Question Sets with 7 learning questions
Control Systems	System response with zeros	1 Animation with 5 steps 3 Question Sets with 13 learning questions
Control Systems	Block diagrams	4 Animations with 5, 5, 4, and 4 steps 3 Question Sets with 9 learning questions
Control Systems	Stability Introduction	0 Animations 2 Question Sets with 4 learning questions
Control Systems	Steady-state error for unity-feedback systems	2 Animations each with 4 steps 4 Question Sets with 11 learning questions

Control Systems	Steady-state error for disturbances	0 Animations 2 Question Sets with 4 learning questions
Control Systems	Root Locus Techniques Introduction	0 Animations 2 Question Sets with 8 learning questions
Control Systems	Defining the root locus	1 Animation with 7 steps 0 Question Sets
Control Systems	Properties of the root locus	1 Animation with 6 steps 2 Question Sets with 6 learning questions
Control Systems	Sketching the root locus	1 Animation with 6 steps 4 Question Sets with 14 learning questions
Circuit Analysis	System of units	1 Animation with 6 steps 2 Question Sets with 9 learning questions
Circuit Analysis	Basic quantities	2 Animations with 6 and 5 steps 5 Question Sets with 15 learning questions
Circuit Analysis	Circuit elements	0 Animations 3 Question Sets with 14 learning questions
Circuit Analysis	Ohm's law	0 Animations 5 Question Sets with 15 learning questions
Circuit Analysis	Kirchhoff's laws	2 Animations with 6 and 5 steps 4 Question Sets with 14 learning questions
Circuit Analysis	Series and parallel resistor combinations	0 Animations 2 Question Sets with 12 learning questions
Circuit Analysis	Superposition	2 Animations with 9 and 8 steps 3 Question Sets with 13 learning questions
Circuit Analysis	Capacitor and inductor combinations	0 Animations 4 Question Sets with 15 learning questions
Circuit Analysis	First-order Circuit Analysis	4 Animations with 4, 9, 9 and 11 steps 5 Question Sets with 23 learning questions
Circuit Analysis	Second-order Circuit Analysis	3 Animations with 8, 5, and 5 steps 2 Question Sets with 14 learning questions