A Thesis

entitled

Attitudes Toward and Usage of Animations in an Interactive Engineering Textbook for Material and Energy Balances

by

Sidney J Stone, III

Submitted to the Graduate Faculty as partial fulfillment of the requirements for the

Master of Science Degree in

Chemical Engineering

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Abstract

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Interactive textbooks generate big data through student reading participation, including animations, question sets, and auto-graded homework. Here, animations are multi-step, dynamic visuals with text captions where records of students' clicks confirm usage and view time. These multi-step animations divide new content into small chunks of information that engage the student, require attentiveness and interaction, and align with tenets of cognitive load theory.

Animation usage data from an interactive textbook for a chemical engineering course in Material and Energy Balances (MEB) is studied. This thesis uses MEB zyBook data collected across five cohorts between 2016 and 2020. Two metrics capture animation usage: 1) fraction of students watching and re-watching animations, 2) length of animation views. In addition to variation across content, parsed by book chapter, five animation characterizations investigate student usage for different types of visuals (Concept, Derivation, Figures and Plots, Physical World, and Spreadsheets). In addition, pre- and post-surveys for one cohort in 2021 assessed students' attitudes about engineering and animations.

The three important findings of the animation view data are 1) student animation usage is very close to or greater than 100% for all chapters, 2) median view time varies from 22 s for 2-step animations to 59 s for 6-step animations - a reasonable attention span for students' cognitive load, 3) Median watch time by characterization ranged from 40 s for Derivation to 20 s for Physical World. Finally, student attitudes about engineering and animations found small, positive shifts that were not statistically significant between pre and post surveys.

Dedication

This thesis is dedicated to my paternal grandmother, Mary H. Stone, who taught me to work hard, and never stop learning.

Acknowledgements

I am acknowledging my advisor, Dr. Matt Liberatore, Professor Chemical Engineering Department who has provided valuable guidance, innovation, and opportunities to investigate this work about animations in education. The special studies about STEM education introduced me to the cognitive load theory, methods of teaching in the classroom and other instructional methods that exceeded my expectations of this Master of Science degree. I appreciate the opportunity as a Graduate Assistant in MEB to observe and be part of these instructional methods being demonstrated.

I also acknowledge that Dr. Yakov Lapitsky Professor, Chemical Engineering Department and Graduate Program Director who was willing to support my dream of STEM instruction with enrollment support in 2019. I was afforded an opportunity to pursue this goal because of his guidance and support that I appreciate very much.

I also acknowledge Dr. Thehazhnan Ponnaiyan who provided guidance in my first Graduate Assistant role in the Unit Operations Lab. His integration of safe lab practices and student interfacing during COVID-19 encouraged compassion and learning for students in a virtual environment.

I also acknowledge Brianne Crocket's assistance with using the Python software and the support of Dr. Kevin Xu in the preparation and generating the view time figures.

I also want to thank contributions from Katherine Roach and Uchenna Johnbosco Asogwa. This material is based upon work supported by the National Science Foundation under Grant No. DUE 2025088. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation. This work was completed within the framework of University of Toledo IRB protocols 300853 and 300721.

Finally, and most important overall, I acknowledge the individual closest to me during this journey my wife Kolleen Stone who has supported my dreams of STEM instructions and put up with long hours, frustrations and through all this continued to support my efforts. Kolleen's encouragement to press on during tough times were an important inspiration.

If it was easy, everybody would do it!

Thanks to all for enabling me to make this goal a reality.

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List of Abbreviations

CLASS ....Colorado Learning Attitudes about Science Survey

C.................................Concept, animations that present conceptual thought or ideas dynamically.

D.................................Derivation, animations that present equations or calculations based on first principles in the form of a dynamic explanation or basis for an equation.

FP ....Figures & Plots, animations presenting dynamic means of managing information in table chart, or list format.

MEB ....Material and Energy Balance

PW..............................Physical World, animated examples of how a system or process works

SS ....Spread Sheet Principles, animations describing data tables used in MS Excel including cell formatting, keystrokes, special functions, and features.

STEM ....Science, Technology, Engineering, and Mathematics

zyBook ....an electronic, interactive textbook publisher and a division of John Wiley & Sons, Inc.

List of Symbols

s ....seconds

Preface

I have been working in industry since graduating with BSc in Chemical Engineering. My career has covered the spectrum from detailed engineering design to project management in power generation and petroleum refining and the journey has been interesting and satisfying. During this career I have had several rewarding opportunities to teach and mentor engineering co-op students and newly hired engineers which has been a rewarding experience.

The purpose of pursuing a Master of Science degree in Chemical Engineering and making this contribution is three-fold: 1) to be refreshed in core technical material; 2) to understand technological advancements and their application in engineering in the technical and educational areas; 3) to learn and apply educational techniques to be an effective teacher. Achieving these objectives are foundational for my desire to teach, coach, and encouraging students in STEM.

The area of greatest impact from these new skills and the preparation of this thesis is that the approach to cognitive learning comes in a variety of formats and impacts student learning in different ways. This study on animations has presented a better understanding of learning methods. I trust that I can incorporate these skills with my work experience and provide practical applications for students in a Junior College or undergraduate curriculum to help them learn, build their technical knowledge, and keep them excited about engineering to prepare them for employment.

Chapter 1 Introduction and Background

Internet access makes viewing information on virtually any topic available to billions of people across the globe. Technology advancements for more than a century in health care, household conveniences, transportation, communication, and computing technology have improved human lifestyle and the human experience. Advancements in affordable screens and devices enabled high quality images, animations, and high-definition video on topics from entertainment to household repair demonstrations.

Some in higher education are using these technological advancements to change traditional 20^{th} century textbook and lecture courses into active student instruction [1]. Undergraduate students entering engineering programs in the 21^{st} century may also be exposed to interactive instruction and are inclined to prefer digital technology for instruction [2]. These students categorized as the “Net Generation”, “Millennials students”, or “digital natives” [2, 3] have an inclination for learning through visual means where “chunks” of material are presented. Educational animations provide one such platform to explain, present, and scaffold learning [4, 5].

Animations have been recognized as a promising tool to bring visual and textual information together to present instructional material [6]. On one hand, computer generated animations used for on-line gaming, films, cartoons, and broadcast media have emerged for entertainment. On the other hand, educational animation are not for entertainment and may be broadly defined as using technology to create the projection of humans perceived phenomena designed to interact with human sensory environment for learning [7]. Some early research in animation instruction failed to provide positive evidence for their use [8, 9]. Further research applying cognitive load theory design criteria for educational animations resulted in positive learning gains with educational animations. [6, 10-16].

Interactive textbooks enable students to see and use animations for active learning or “learning by doing” [17-19]. Animations may be considered a form of active learning and research has shown applying cognitive load theory to animations improves student learning and retention [1, 4, 14, 18, 20-22]. The influence and familiarity of electronic devices among the student population makes interactive learning an appealing platform for higher education students [2]. An animation is a sequence of visual steps that introduce and move images, figures, and text to explain or convey a concept. Educational animations included in an interactive textbook are designed to provide information in sensory format that considers student cognitive load for learning and educational purposes [8, 10, 14, 23]. Multi-step animations content divides the content into small chunks of information that engage the student and require attentiveness. Animation re-watch may be initiated at any time [8].

This thesis addresses two areas of animation research: first, the views and time spent watching animations; second, students’ attitudes about engineering and animations.

1.1 Features of Educational Animations

Static images in the form of tables, figures, and graphs presented in engineering textbooks rely on text that supports explanations and derivations of the technical content. Flipping pages between the text and these images can be distractive for the learning process because the information is dispersed. While the information may be presented in the text along with the associated images, the information is not guided and may require significant cognitive load.

Research in Cognitive Load Theory presents three categories of cognitive load on the working memory [24]. Intrinsic cognitive load is defined by learning task complexity and interactivity; extraneous cognitive load involves the tasks that cause unnecessary interaction of the senses and may inhibit learning; germane cognitive load is the remaining working memory available for learning.

Non-educational animation advancements with digital technology bring imagination to life through games, videos, and movies with computer-generated action that holds user attention. Animation used for entertainment may have learning value and student familiarity with animation lends itself to engaging the user. However, animations for entertainment focus on engagement and storytelling, which typically does not apply the principles of Reflection, Feedback, or Pacing for students in the learning environment defined by cognitive load theory of multimodal learning environments and educational animation design considerations [17, 25].

Educational animations research on learning and instruction applies the Cognitive Load Theory framework to design animations for learning by reducing the cognitive load on working memory. Multimedia instruction is defined as learning through the use of pictures and words that construct mental representations for learning [12]. Multimodal learning incorporates the use of different senses and processing abilities of the memory to learn and has identified that educational animations require unique features to support learning [17]. Text (words) and visual (pictures) are the instructional media for integrating, organizing, and retrieving long term memory (Figure 1.1).

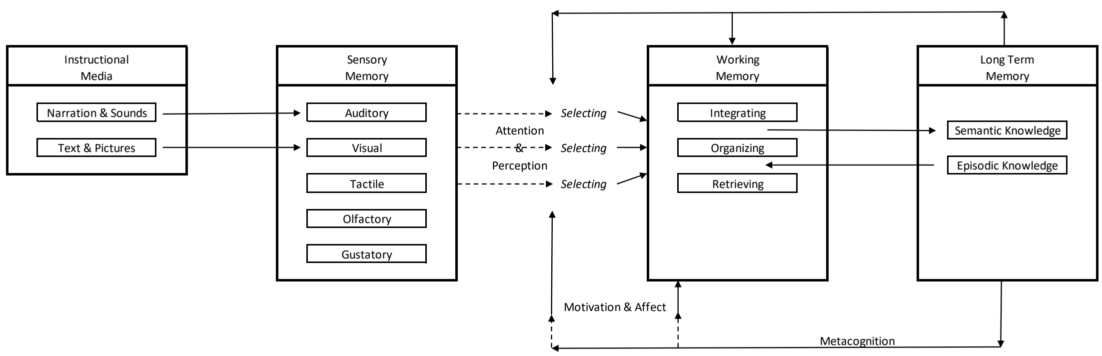

Figure 1.1 A Cognitive-affective model of learning with media [17]

Five principles to guide interactive multimodal learning have been identified [17]. The five empirically-based principles are: 1) guided activity that prompts students to engage in the selection, organization and integration of new information; 2) reflection that promotes and encourages active organization of new information; 3) feedback provides students with explanatory information for proper thinking and correct misconceptions; 4) pacing enables students to view and process smaller chunks of information in working memory; 5) pretraining that guides the student in the generative process to link new information with prior knowledge.

Thus, for educational purposes, animations must consider how people learn and what information is required or should be eliminated to support learning. Application of these five research principles will be elaborated upon with respect to the interactive textbook used in this research.

The Material and Energy Balance (MEB) zyBook interactive textbook contains animations that were designed for educational purposes. Multiple student-initiated steps using clicks advance through the animation sequence. This multi-step design applies the five principles for design principles of cognitive load theory of multimodal learning.

The guided activity principle is applied in the MEB animations with students' interaction and engagement requiring only mouse clicks. The animation includes a START button for initiating the sequence and subsequent steps are selected until the animation is complete. No additional, or extraneous, screen navigation is required once the animation is started, and the only physical action of the student is to click the forward arrow as desired once the previous set concludes.

The reflection principle is applied in the MEB animations in several ways. First, the animations final and complete visual is displayed initially as a static image, which can be viewed before or after watching the animation. Next, most or all of the visual disappears, and each animation step presents chunks of new visual information as well as a caption. Since the student may take time to process the new information of the completed step prior to initiating the next step, reflection on each completed step is possible. The animation may be partially or completely re-watched.

The pacing principle is applied in the MEB animations dynamics by bringing the text and graphics together into small chunks of information for student control, attentiveness, and interaction. Individual student control paces information presentation. Pacing provides student control and enables re-watch of animation steps to reinforce or review material at any time.

The pretraining principle is applied in the MEB animations by building on knowledge gained from introductory courses in chemistry, physics, mathematics, and biology prior to taking the course. In addition, graded reading assignments introduce students to valuable new material outside of class in preparation for class time exercises. The reading assignments provide deadlines and spread out knowledge gains that avoid cramming. Research of student textbook reading has identified low participation rates [26].

1.2 MEB Interactive Textbook Data

The research in this thesis is based on 2016 and 2020 data gathered from the interactive zyBook textbook used for The University of Toledo CHEE2010 Material and Energy Balance (MEB) chemical engineering course. Student participation data is generated by student mouse clicks while progressing through different assignments which include reading participation, animation views, and challenge activities, which are a form of auto-graded homework. The animations are spread across almost every section and chapter (Table 1.1).

Table 1.1 MEB zyBook Chapter titles and animation count by year

		Year					
Chapter	**Chapter Title**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
1	Quantities, Units, Calculations	9	9	9	9	9	10
2	Material Balances	19	19	19	19	19	19
3	Reacting Systems	11	13	13	13	13	13
4	Solids, Liquids, and Gases	9	10	11	11	14	14
5	Multiphase Systems	8	13	13	13	15	15
6	Energy Balances	8	8	15	15	15	15
7	Reaction and Energy Balances	5	5	7	7	7	7
8	Transient Systems	3	3	4	4	4	4
9	Spreadsheets	N/A	N/A	41	41	47	47
All	**Total Animations**	**72**	**80**	**132**	**132**	**143**	**144**

1.3 Student Attitudes About Engineering and Educational Animations

The second area of research in this thesis is students' attitude about engineering and animations. Student selection and pursuit of science/engineering careers has been linked to their attitude and perceptions of the discipline [27, 28]. Assessing STEM student attitudes supports continuous improvement, student motivation, and learning progress from novice to expert. Conducting assessments of student attitudes may use qualitative or quantitative tools. Qualitative tools include student interviews that provide insight and clarification directly from students, however interviews require a great deal of analysis time . Quantitative tools, such as surveys, collect student responses as numerical scores are easier to analyze and provide useful insight [29]. Measuring student attitudes about engineering and technical studies are important mental constructs affecting student learning behavior in STEM [30].

The objective of continuous improvement in education is to assess and identify material and exercises in the classroom that went well, that need slight modifications, or have shortcomings or gaps that need improvement. Instructors may apply self-assessment, peer review, or students' assessment [31] (Pg. 161 - 169). A positive correlation of students' and teachers' attitude when technology is integrated into instruction has been measured [32].

Student motivation and learning progress from novice to expert are important assessments to obtain for STEM students. Various survey instruments are available for assessing instructors, student learning expectations, course content, or student engagement [29]. In the student-centered learning environment, however, the configuration of the questions has the objective of assessing how instruction is changing the students' thinking about the material and their beliefs about learning a unique discipline. One best practice in education is to address the formation of attitude, intentions, and behavior that change students' beliefs and progress toward those of experts in a discipline [27].

The purpose of an attitude assessment is to receive student feedback about the classroom experience that may lead to instructional improvements. Measuring the novice-to-expert progress of students, enjoyment in a discipline, and the ability to make connections between the theoretical concepts and real-world applications for a career are desirable [33]. The attitude change is an indicator of student progressive success from novice to expert along the journey to a career in the sciences [34]. In addition, an attitudes survey can evaluate teaching interventions and their ability to develop problem solving skills as well as an appreciation of the practical application of the course material.

The Colorado Learning Attitudes about Science Survey (CLASS) is one quantitative instrument that collects student beliefs about a specific science subjects based on their knowledge about the subject and compares these beliefs to experts responses that distinguish the student progression from novice to expert [27, 35]. The original design of CLASS was for physics and has since been validated and used in other disciplines including chemistry, biology, astronomy, and mathematics. Using CLASS demonstrates that a positive attitude toward STEM studies correlates with academic success and learning to retain students in science careers [27, 28, 35]. One purpose of this thesis to assess changes in student's attitude toward animations while using an interactive textbook in an undergraduate chemical engineering course.

CLASS has demonstrated that a positive attitude toward STEM correlates with academic success, student retention, and career success in the sciences [36]. The CLASS instrument has been modified and adapted to various science topics for similar assessments. In the CLASS application for MEB the adaptation revised the science topic from physics (CLASS version 3) to engineering and involved revising 36 of 41 available questions which were validated by two chemical engineering faculty to verify expert responses . One attention check question remained [27, 28].

Specifically, this thesis is organized into two parts. First, Chapter 2 studies the animation usage and view data from an interactive textbook MEB course. Second, Chapter 3 presents and studies the results of the CLASS instrument applied to MEB evaluating attitudes about engineering and animation use. This thesis does not discuss the learning benefits of these animations with the cognitive processes which is an area for future research. Conclusions and recommendations are included in Chapter 4.

Chapter 2 Usage of MEB Animations

This thesis uses big data generated through different ways from an interactive textbook for a Material and Energy Balance (MEB) chemical engineering course. Data is generated as students click through each of the multi-step animations. The clicks are time stamped upon initiation and/or completion of each animation step; records of completed views for each animation are also collected. This click data was collected by zyBooks for all students completing any activity in the interactive textbook during the semesters of interest. The data is organized by time stamp, anonymous student identification number, and animation. Animation click data for five cohorts between 2016 and 2020 cohorts are investigated here.

A series of research questions evaluate and analyze aggregated animation usage and view data. First, do students view all steps in animations and what is the rate of re-watched animations? Second, how long do students watch animations? Third, dividing animations into five unique characterizations, does view rate or time vary between characterizations?

2.1 Materials and Methods

The University of Toledo CHEE2010 Material and Energy Balance (MEB) chemical engineering course has been using a zyBook interactive textbook since 2016. The author and instructor of the zyBook textbook is Dr. Matthew Liberatore, Professor in the Chemical Engineering Department. Dr. Liberatore has been instructing MEB with the zyBook each spring semester with varied student enrollment (Table 2.1). The five cohorts are similar in number, and animation views account for student withdrawal. Students are primarily freshman majoring in chemical engineering or environmental engineering with approximately 60% male and 40% female [37]. Student participation data is generated through either reading or homework assignments, which include reading participation, animation views, and Challenge Activities, i.e., a form of auto-graded homework.

Table 2.1 MEB Semester enrollment

	Initial Enrollment	**Final Enrollment**
2016	104	100
2017	93	89
2018	104	99
2019	103	98
2020	104	94
Total	**508**	**480**

The MEB course is a 3-credit hour course and meets on Monday, Wednesday, and Friday for the spring semester. Animation view data recorded through clicks during the reading assignments are collected across cohorts and this completed view data is used and analyzed and answering the research questions.

The configuration, course content, and instructional approach of the interactive textbook for MEB supports the pedagogy of active learning. This approach focuses on the students "learning by doing" where class time is used to review material, present example problems and solutions, and allow students to work on solving new problems during class time [4]. The active learning research identifies that this teaching technique yields learning benefits as well as encourages team building, group discussion, and peer assistance, which are skills needed for students' careers.

The details of the MEB course contents are not covered in this thesis since the focus is on animations. However, a brief description of how the course is designed and how the material is covered is provided by summarizing the three components of student participation in the course: 1) Reading Assignments, 2) Challenge Activities, and 3) Homework Assignments.

Weekly, low-stakes graded Reading Assignments are designed to encourage student reading and follow the in-class content. Reading assignments include watching animations and answering multiple choice, true/false, or matching questions to build concept learning. The interactive textbook reading assignments document students' clicks and uniquely record activity including individual sequenced steps of the animations. One animation titled Finding bubble and dew points on a P-xy diagram (Appendix A-4) is an example of an animation frequently re-watched by students and is included along with an explanation of the sequence. Reading assignments are typically due on Mondays, and class time is arranged to review concepts and example problems followed by small group assignments that are solved during 15 to 30 minute segments of class time.

The zyBook collects all activity data for any activity. The completed animation views are evaluated in this thesis (Table 2.2).

Table 2.2 Completed MEB animation views per chapter by year

Chapter	Chapter Title	2016	2017	2018	2019	2020	Total Views Rounded
1	Quantities, Units, Calculations	1731	878	1016	1010	1036	5700
2	Material Balances	2518	1810	1997	2082	2002	10400
3	Reacting Systems	1254	1453	1436	1457	1472	7100
4	Solids, Liquids, and Gases	1027	969	1220	1205	1493	5900
5	Multiphase Systems	1014	1338	1427	1478	1495	6800
6	Energy Balances	820	788	1550	1655	1582	6400
7	Reaction and Energy Balances	493	460	716	745	705	3100
8	Transient Systems	293	258	382	404	364	1700
9	Spreadsheets	0	0	4169	4150	4598	13000
All	**Total Completed MEB Animation Views**	**9150**	**7954**	**13913**	**14186**	**14747**	60100

Challenge Activities require problem solving, which builds upon the Reading Assignments. Challenge Activities are auto-graded homework with scaffolded questions across multiple levels. In many cases, problems similar to the Challenge Activities were reviewed during Wednesday's class time for further reinforcement. Challenge Activities provide immediate feedback and allow for multiple attempts without penalty. Each question has multiple versions. Auto-graded questions generate a fraction of students correctly answering, attempts before first correct response, and total attempts on each question. Challenge Activity assignments are typically due on Wednesday before class time. Some Challenge Activity problems align with a weekly quiz administered during part of Wednesday's MEB class time.

Homework assignments are summative problems typically due on Fridays. The end of chapter exercises does not have immediate feedback like Challenge Activities, are submitted as handwritten work to mimic in class quizzes and exams. The problems align with the topics covered during the week, the next weekly quiz, and build knowledge and practice for the exams. Friday class time is another opportunity for small group problem solving.

Animation usage is included in the assigned reading of the interactive textbook, the students' clicks are uniquely recorded from the individual animation sequenced with different steps as animations are viewed through all steps to completion. Evaluating the time spent by students to complete watching and re-watching the animations from 2017 through 2020 cohorts was compiled and used for answering the research questions. 2016 was removed from this analysis because a 2X (double speed) feature was added to the zyBooks to speed the viewing of the animations between the 2016 and 2017 cohorts.

Student view time is defined as the time students spend viewing zyBook animations on a stepwise basis. The students' clicks are time stamped from viewing individual animation sequenced with different steps with examples shown for completed animation with 2, 3, 5 and 6 steps (Appendix A-3). A 4-step animation sequence shows all the steps with the text and figure progress (Appendix A-4). The initial static image of the animation includes a "Start" button (not shown) and once initiated, the animation begins Step 1. The arrow to the right of the step numbers appears when the step is complete. Clicking the arrow continues the animation and builds on the previous steps to completion. The final step completes construction of the initial static image, and a completed view is recorded. Second or subsequent watching by a single student is called re-watch and may be initiated at any time.

Animation usage data analysis was done using spreadsheet functions, pivot tables, or statistical analysis using Python. Animation usage accounts for the animation view data and does not consider the time spent watching or re-watching the animations. Completed animation views are logged when a student has completed all the animation steps and represent student participation in watching animations.

Animation view time accounts for the time students spend watching, reflecting upon, or re-watching each animation step and animations as a whole. For example, each step has a minimum duration after which students may reflect or immediately click to initiate the next step of the animation. About 60,000 views (Table 2.2) were generated and analyzed. The logged time stamped clicks are generated from student reading assignments, and the data used in this section only includes time spent on the animations (Appendix B, columns A, B, C, and D).

Python and several Python libraries were used for analysis of the timestamp data. The Pandas library calculated step timed as the difference between the logged events for each student on each animation. View time was calculated as the sum of a student's step times from the "start clicked" event to the "animation completely watched" event. The animation view time will be analyzed by aggregate (all cohorts), year, chapter, and total steps in an animation.

Animation characterization considers the type of content in an animation. The animations may involve the physical world, deriving equations, explanation of concepts, figures, or spreadsheets. The characterization descriptions (Table 2.3) were defined to evaluate how the animations content may influence watch rate or time.

Table 2.3 MEB zyBook animation characterizations

Abbreviation	**Description of Animation Characterization Content**
PW	Physical World, animated examples of how a system or process works
D	Derivation, animations that present equations or calculations based on first principles in the form of a dynamic explanation or basis for an equation
C	Concept, animations that present conceptual thought or ideas dynamically.
SS	Spreadsheet, animations including cell formatting, keystrokes, special functions, and formulas.
FP	Figures and Plots, animations presenting information in table chart, or list format

2.2 Results and Discussion

Animation usage research questions are: do students view all steps in animations and what is the rate of animation re-watch across the chapters?

Animation views as a percentage are calculated by dividing total completed views by total students and accounts for student withdrawal. Average animation watch rate was

110% across five cohorts. Thus, about 10% of animation views were students re-watching the course content. The average cohort watch rate declined from 124% (2016); 114% (2017); 108% (2018); 107% (2019); 105% (2020). Despite the declining re-watch rate over time (Table 2.4), these results are significant. To compare, static textbook reading rates are normally reported between 20% and 50% [26]. The highest re-watch in 2016 may be due to the premier use and novelty of the zyBook. Also, the decline in the average may be due to increased animation count in the zyBook (Table 1.1) across the cohorts. However, animation count increased by 65% from 80 animations (2017) to 132 animations (2018) and does not correlate with the 5% decline in watch rate.

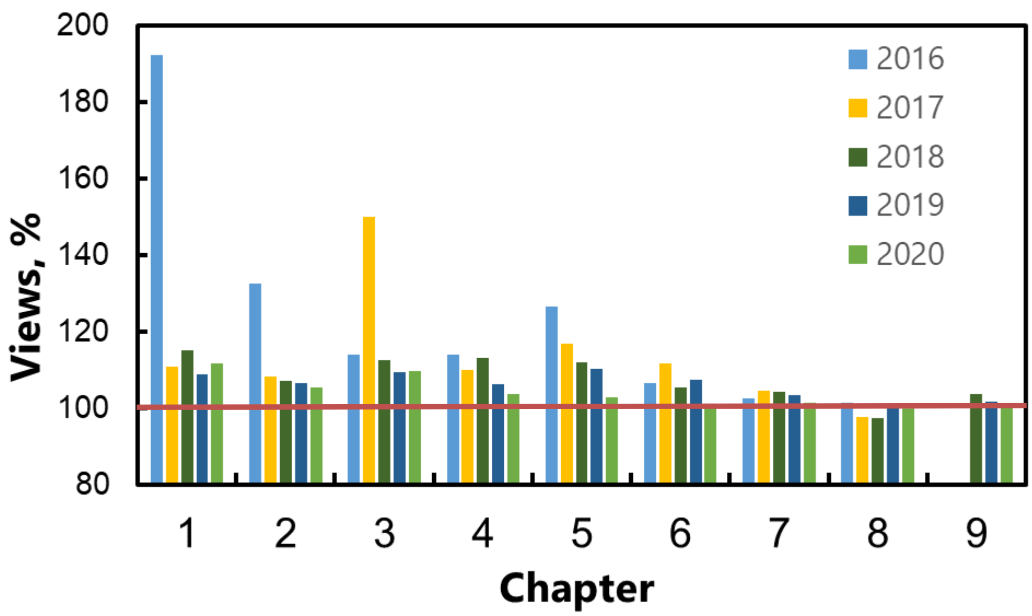

Figure 2.2.1 2016 through 2020 ZyBook Animation Total Views by Chapter

Animation views by chapter were generally over 100% across the cohorts (Figure 2.2.1); the exceptions were 2017 and 2018 Chapter 8 views of 97 to 98%. Values below 100% for Chapter 8 may be expected since this course material is only assessed with a single quiz and not covered on the final exam.

The animation re-watch views by chapter (Figure 2.2.1) are generally 1% to 15% with a few outliers, re-watch > 20%, in 2016 and 2017. The high re-watch rates in 2016 are noteworthy (Chapter 1: 92%, Chapter 2: 33%, and Chapter 5: 27%). Possible explanations include high student interest in the premier year of an interactive textbook. Early semester reading and homework assignments are generally not heavy, so students may have re-watched the material due to the new format. In 2017, Chapter 3 re-watch reached 50% and may be due to the newness of the textbook and students' need to be refreshed on chapter content. Material covered in Chapters 3, Reacting Systems (conversion, extent of reaction and recycle) and Chapter 5, Multiphase Systems (Raoult's law, flash, absorption, and stripping) contain key concepts and methods critical for exam preparation and may be the reason for high animation watch rates. Chapter 9 was introduced in 2018 and re-watch views between 1 and 4% may be due to familiarity and no quiz or exams questions.

Consistent animation views from 2018 through 2020 are also noted. Analyzing Chapter 1, 2, and 3 (Table 2.4) the re-watch rates were consistently in the range of 6% to 15%. Results above 100% for watch rates may be due to students building on prior course knowledge, adding new concepts, and being genuinely interested in understanding the new material. Chapters 4, 5, and 6 re-watch rates declined from 13%, 12%, and 5% for 2018 to 4%, 3%, and 1% for 2020. Student enrollment by chapter was accounted for and re-watch decline is not due to student withdrawal. The decline in % watch for Chapters 4, 5, and 6 is surprising since the information in these chapters includes core course material. The Chapters 4, 5, and 6 assignment timing is well into the semester and a possible reason for the decline in re-watch is increased course load and reduced time available for re-watch. Chapters 7, 8, and 9 watch rates are consistent across the cohorts near 100%. Material in Chapters 8 and 9 are not included on exams, which is a probable reason for the low re-watch rates.

Two limitations are noted when discussing animation views. First, the analysis does not investigate partial views – many animations have 4 to 6 steps and re-watching some steps is likely. Secondly, animation views do not account for the length of time watching an animation or how long students may reflect after individual steps. Animation view time is further investigated in the next section.

The animation view time research objective is to determine, analyze, and discuss the differences in view time for each animation. Six animation view time related research questions are evaluated using the time stamped data. First, what is aggregate view time for all animations? Second, what is the animation view time by cohort? Third, what is the animation view time by chapter? Fourth, what is the animation view time by number of steps? Fifth, what is the first and second animation view time by chapter? Sixth, what is the aggregate view time of first, second and third animation view attempt?

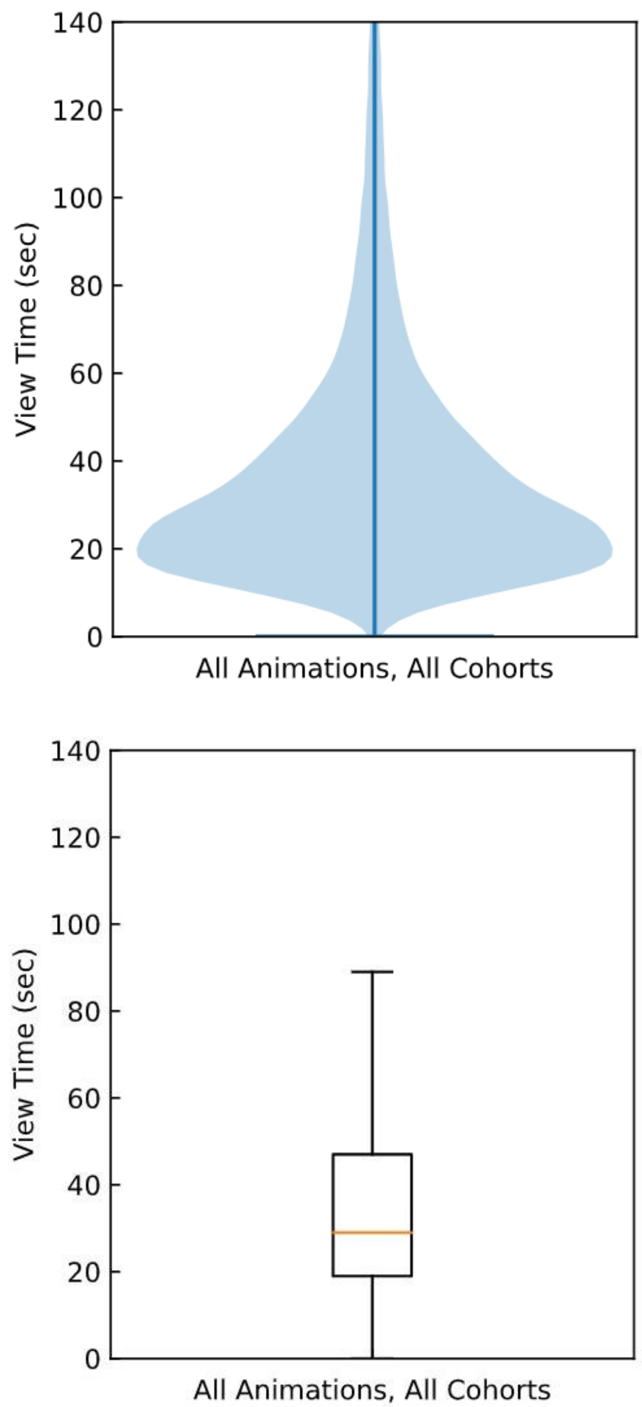

Figure 2.2.2 Top. Violin Plot - aggregate view time for all animations. Bottom, Box and Whisker Plot - aggregate view time for all animations.

The aggregate view time for all animations as a violin plot (Figures 2.2.2) identifies a mean view time of 20 s. The aggregate view time for all animations as a box and whisker plot (Figure 2.2.2) identifies the median view time of 30 s, value at 25th percentile of 20 s, and the value at 75th percentile of 50 s for first attempt student animation views. These animations views are intentionally short, similar to short video clips, to match student short attention span and build up textbook reading rates which are traditionally low [18, 38]. Specifically, animation durations of 30 to 120 s are similar to video clips of the same length [38]. The top of the whisker view time of 98 s is also reasonable to keep students' attention. Maximum view times for any single animation were limited to 180 s for data analysis. Watch time varies may depend on number of steps, time reflecting on the image, reading the captions or other reasons that may be explored at a future time.

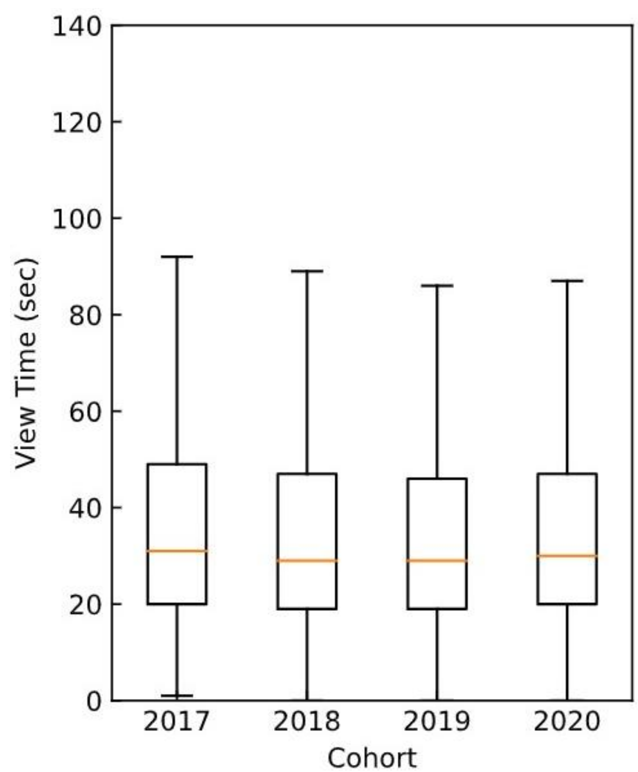

Figure 2.2.3 Box and Whisker Plot - cohort view time for all animations

First animation view times by cohort (Figure 2.2.3) identifies a consistent 1st quartile of 20 s, and a 3rd quartile of 45 s to 47 s. The median was consistently 30 s. The consistency between cohorts shows statistical similarity (ANOVA data).

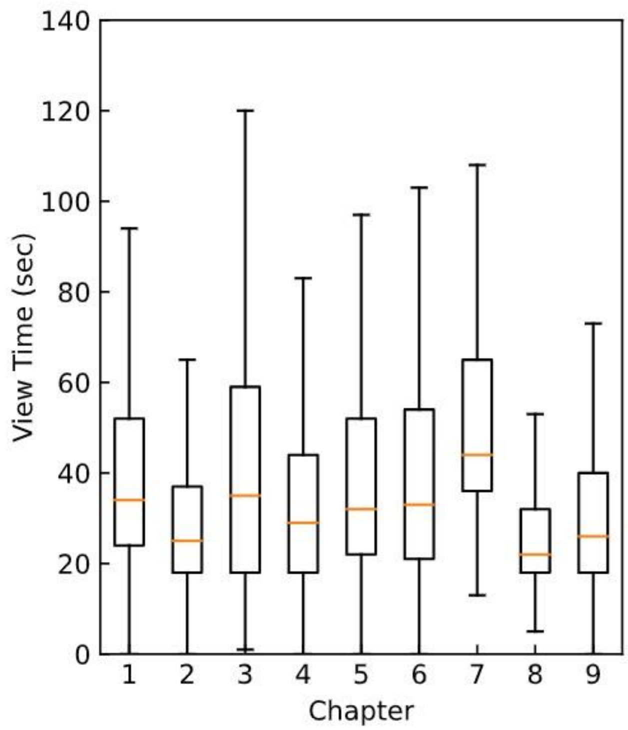

Figure 2.2.4. Box and Whisker Plot - chapter view time for all animations

The aggregate animation view time by chapter (Figure 2.2.4) shows the median first attempt student animation view time by chapter ranges from 22 s (Chapter 8) to 42 s (Chapter 7). Overall, the differences in the number of animations, content, and number of steps likely drive the variations in view time by chapter. To assess this difference, the animation view time could be divided by the number of steps in the animation to establish a value. Using this approach may be done for each chapter and should be considered for future research.

Cohort average view time of 30 s for all animations (Figure 2.2.3) matches the average median view time of Chapters 1 through 6 within 1 s. Chapter 7 consistently included seven animations and has the highest view time of 42 s which is likely due to 3 of 7 animations covering Derivations and 3 of 7 animations covering Figures and Plots with most of these being 4-steps or more. The value at 25th percentile for Chapters 2 and 8 are 19 s and are close to the median values of 27 s and 22 s respectively and the value at 75% of 38 s and 30 s respectively. Evaluating the Interquartile Range (IQR) of all the chapters identified that the IQR is greater than the median only for Chapter 3 indicating the spread of data is greater from the median which may be influenced by difficult or new concepts animation content. The characterization, or content, and step count of the animations is not defined (Figure 2.2.4) and may also influence the reflection time. Discussion about animation characterization and step count will be discussed further.

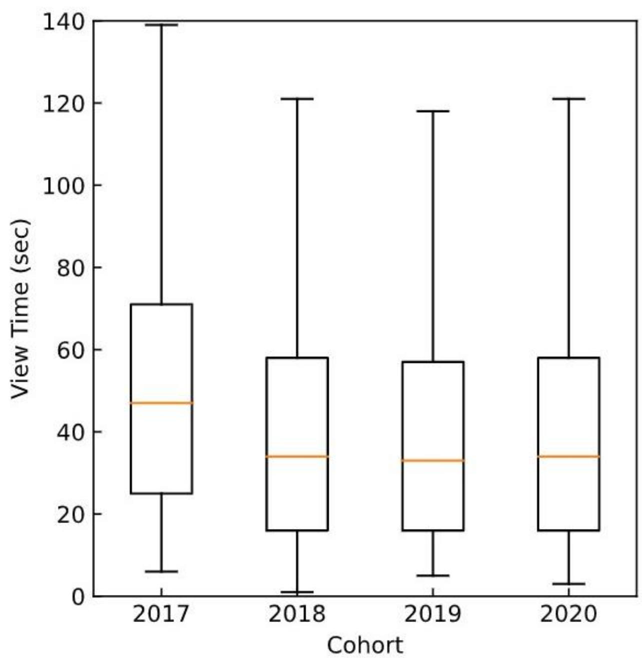

Figure 2.2.5 Box and Whisker Plot – Cohort Chapter 3 animations view time

Another research question examined animation view time by chapter across cohorts. Eight of the nine chapters showed consistent times across the cohorts and should be justified statistically in future research. Chapters 3 has some variation that will be discussed further. Chapter 3 animation view times (Figure 2.2.5) show differences between 2017 and the later three cohorts. The median view time was 47 s for 2017 and 34 s for 2018 to 2020. All cohorts read the same 13 animations in Chapter 3 (Table 2.2), so the difference is noted. In addition, Chapter 3 2017 re-watch rate of 50%, was higher than other chapters (Table 2.3) and may be due to newness of the textbook and students' need to be refreshed on chapter content for comprehensive exams.

Table 2.4 Number of animations by step count

Step Count	Animation Count
2	37
3	37
4	42
5	16
6	7

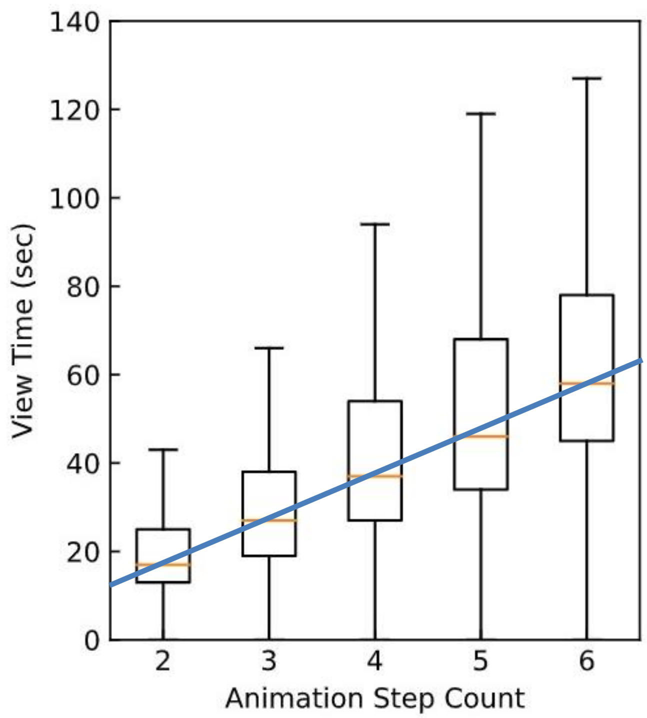

Figure 2.2.6 View time by animation step count

Animations have various step counts (Table 2.5) with step counts of 2, 3, and 4 animation steps as the most common. The number of steps in the animation vary to chunk information in alignment with cognitive load theory. While the content expert creating the animations believes that each step is appropriate, animation view time may test readers attention span if too many actions occur.

The median animation view time by step count increased with the number of steps: 2 step (17 s); 3-step (27 s); 4-step (37 s); 5-step (46 s); 6-step (58 s) (Figure 2.2.6). An example of the various animations by step count is found in Appendix A-3. The superimposed trendline through the median view times with increased step count shows a positive slope of +10 s/step (Figure 2.2.6). A trend line through the 75^{th} and 25^{th} quartile view times have a positive slope of +14 s/step and +8 s/step, respectively. The larger slope of the 75% quartile trendline compared to the slope of the mean view time indicates that many students spend additional time reflecting upon the animations as step count increases, possibly due to internalizing the new content of each step. The lower 25^{th} quartile trendline slope compared to the slope of the mean view time trendline indicate that some students progress through the animations quickly regardless of the number of steps.

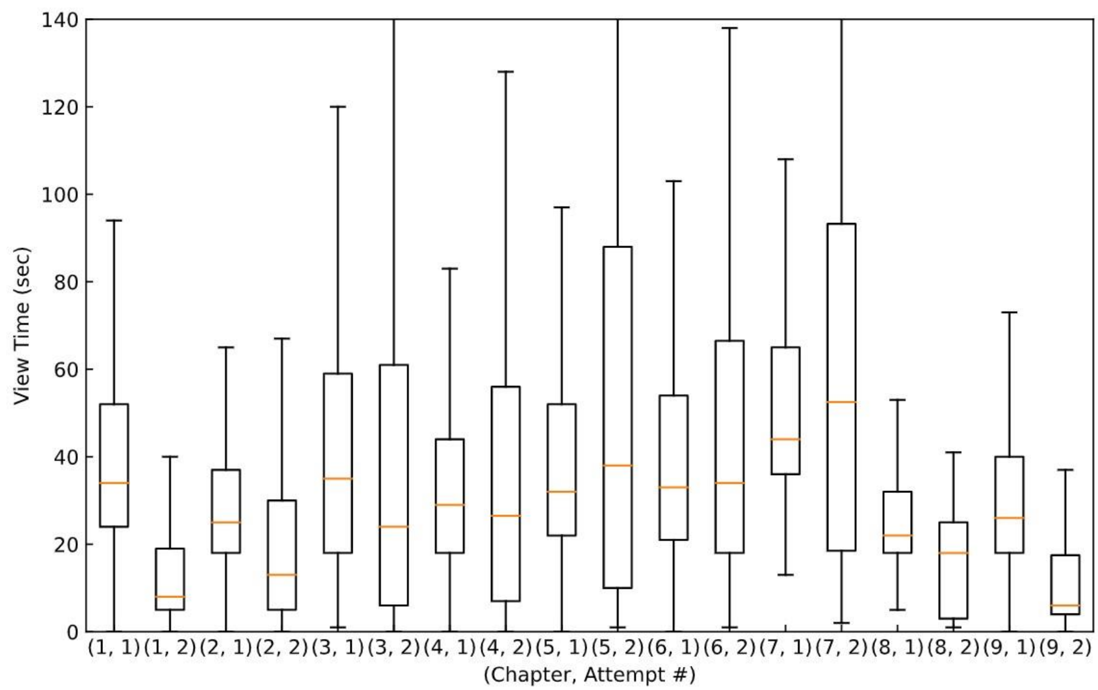

Figure 2.2.7 Box and Whisker Plot – First and second animation view time by chapter

The median view time for first and second animation view time varies by chapter (Figure 2.2.7). Chapters 1, 2, 3, 4, 8, and 9 have lower median view times for second views. However, the increased 75th percentile second view time values for Chapters 3, 4, 5, 6, 7, indicated that some students viewed animations for a longer time on the second view. Particularly noticeable are the increased interquartile range for Chapter 3, 5, and 7; these chapters cover new material commonly included in quizzes and exams. Interquartile ranges of Chapters 2 through 8 increase for the second view from 32% (Ch. 2) to 160% (Ch. 5) shows that students spent more time reviewing content on the second view. The interquartile ratios of view times declined for Chapters 1 and 9 second animation views - 50% (Ch. 1) and – 39% (Ch. 9) and students spent less time reviewing content on the second view, possibly due to familiarity with animations' content.

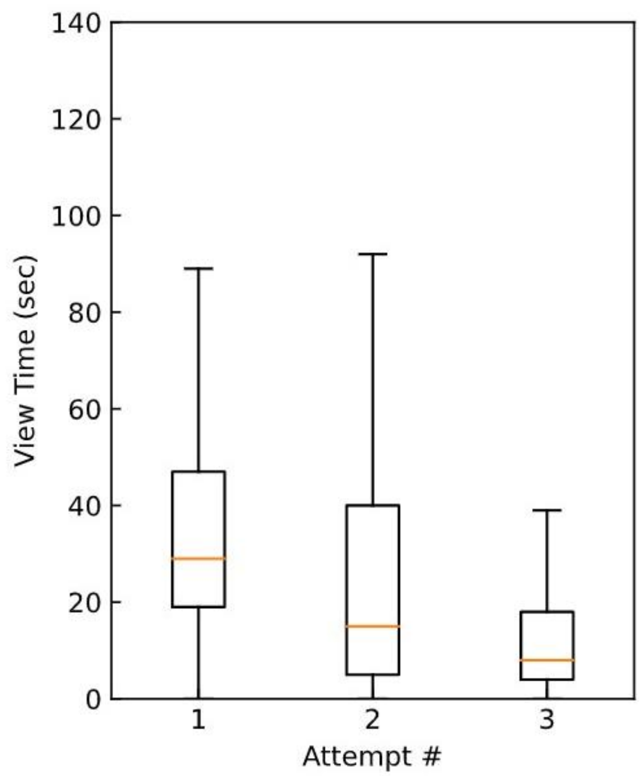

Figure 2.2.8 – Aggregate first, second and third animation view time

The average animation view time declines with re-watching (Figure 2.2.8). From 29 s (first view), 18 s (second view),to 8 s (third view), further analysis is needed. The 25th percentile times declined from 20 s for the first view to 3 s for both second and third views indicating that some students may not re-watch the entire animation and focus on a step of interest. The 75th percentile view time declines a small amount between the first and second views (45 to 40 s) and a much larger decrease of 20 s between the second and third views. Thus, some students may be earnestly re-watching most of the steps during a second view but focusing on one concept during a third view.

Limitation of view time analysis is the inability to evaluate and identify additional student reflection time beyond the minimum time required to complete each animation and evaluate the specific steps that were watched earnestly after the first view. Evaluating reflection time is a recommendation for future research.

Parsing animations by characterization instead of content, i.e., chapter, provides another perspective on the view analytics. The animation count by characterization (Table 2.5) is not evenly distributed between animations characterizations in the zyBook. Since n > 15 for all categories and the number of animations statistical pairwise comparisons will be discussed next.

The animation characterization research objective is to determine, analyze, and discuss the differences in view time for each animation by characterization. Two animation characterization view time related research questions are evaluated using the defined animation characterizations. First, what is the animations count by characterization? Second, what is the view time for each animation characterization?

Table 2.5 Animation Count by Characterization

Animation Characterization	Animation Count
PW - Physical World	30
D - Derivation	30
C - Conceptual	17
SS - Spreadsheet	16
FP - Figures & Plots	50
Total Count	**143**

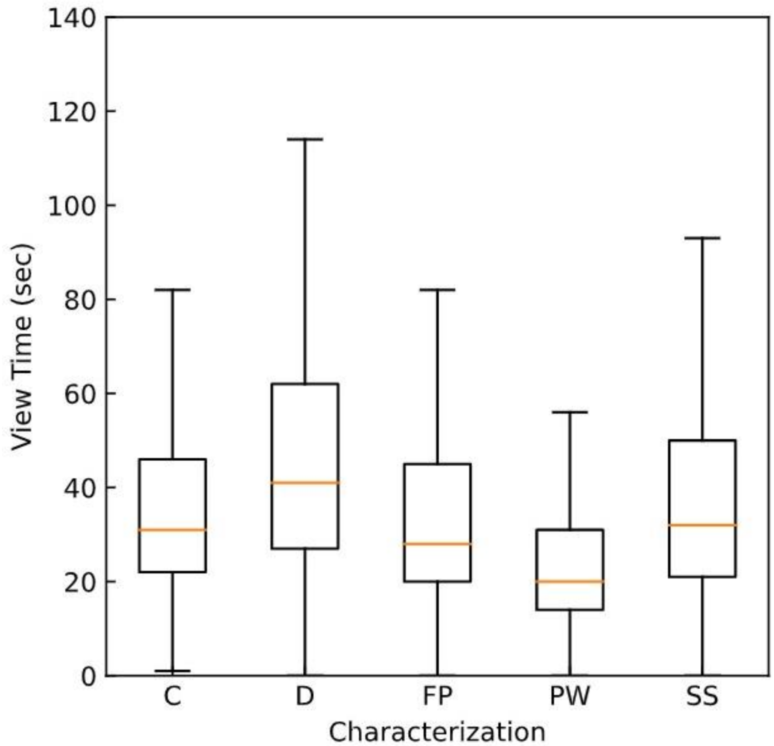

Figure 2.2.9 Aggregate animation view times by characterization

Animations view time by characterization (Figure 2.2.9) shows that Derivations (D) animations have a median watch time of 41 s, which is twice as long as Physical World (PW) animations (20 s). The variation of the median view time by characterization is up to 50%, which merits further exploration. Concept (C), Figures and Plots (FP), and Spreadsheet (SS) animation's median view time is 30 s and 25th percentile is 20 s which match the respective values of cohort view time (Figure 2.2.3). The 42 s value at 75th percentile of C, FP, and SS animations are below the 46 to 50 s cohort time (Figure 2.2.3) and may be due to familiarity with the Concept (C), Figures and Plots (FP) and Spreadsheet (SS) material . Derivation (D) animations introduce new information and, in some cases, have higher step counts which may require additional view time to support the 40 s median view time. The 3rd quartile value for Derivation animations is 60 s and is double the average view time (Figure 2.2.3) which supports the possible difficulty of the new information requiring additional view time. The 25th percentile value of 29 s for Derivation animations matches the average of the other animation view time and is reasonable for student attention of Derivation material.

2.3 Conclusion

Reading assignments support the pretraining principle by introducing new information that prepares students for knowledge gains through class time exercises. Animation usage revealed ~ 100% of students, with minor exceptions, watch animations at least once during the semester. This is a positive outcome since textbook reading in higher education has declined over the years [38]. In addition, aggregate animation results show a non-graded re-watch rate of 10% indicating student self-motivation and interest in learning. Re-watches declined across the cohorts and may also be attributed to the students having a greater workload in the course due to an increase of Challenge Activities, which is outside the scope of this thesis.

Median view time aggregating all animations was 30 s, which is a reasonable time for students with short attention spans. Animation re-watch may be more likely when students know that reviewing/re-watching an animation will take one minute or less in most cases. The median first animation view time by chapter ranges from 22 s to 42 s, which shows that content is not a significant factor in increasing view times. Median view time increased linearly with step count. 2-step animations' median views took 18 s while 6-step animations took 59 s. Median animation view time declined from 29 s (1st view) to 18 s (2nd view) to 8 s (3rd view). The decrease may be attributed to subsequent attempts not being graded; however, many students reviewed the interactive animations, and repetition is a best practice of learning.

View time by characterization showed that Derivation (D) animations has the longest median time of 41 s, which is twice as long as view time for Physical World (PW) animations at 20 s; Figures and Plots (FP), Conceptual (C), and Spreadsheet (SS) animations' watch times were in between.

Chapter 3 Assessing Attitudes About Engineering and Animations

Student attitudes are important for attracting and retaining STEM students. Students' beliefs shape their disposition for learning science and retaining a positive attitude of enjoyment while progressing in their field supports persistence.

The research objectives are to evaluate MEB students' attitude about engineering learning and use of animations in an interactive textbook. Attitude measurements are an indicator of discipline enjoyment, student ability to make connections between the theoretical material and the real-world applications, and technology applications [33].

A wide variety of attitude assessment tools are available, one of which is the Colorado Learning Attitudes About Science Survey (CLASS) [29]. CLASS was originally used to assess student attitudes about physics. Over time, CLASS has been modified and used to assess other STEM courses including chemistry, biology, astronomy, and math [27, 28]. In 2018 CLASS was modified for engineering and administered in MEB to measure attitude shift [28]. The spring 2021 MEB course administered the modified CLASS and results are discussed in this thesis. Students' attitudes for both engineering and use of technology, particularly with interactive textbooks that include animations, need to be understood to retain students in STEM.

3.1 Materials and Methods

The configuration of the CLASS for spring 2021 MEB replicated the format of the 2018 instrument, including one attention check question (Question 32) , to match the 42 core CLASS questions related to engineering (Table 3.1). In addition, 9 animation-specific questions followed the 42 core CLASS questions to investigate student attitudes on the use of animations in an interactive textbook (Table 3.2).

Table 3.1 42 Questions of CLASS engineering attitudes survey

Question Number	Expert Response	Statement
1	N/A	University of Toledo Department of Chemical Engineering Nitschke Hall, Third Floor, Room 3048 1610 North Westwood Avenue Toledo, OH 43606 ADULT RESEARCH SUBJECT - INFORMED CONSENT FORM Student a...
2	Disagree	A significant problem in learning engineering is being able to memorize all the information I need to know.
3	Agree	When I am solving an engineering problem, I try to decide what would be a reasonable value for the answer.
4	Agree	I think about the engineering I experience in everyday life.
5	N/A	It is useful for me to do lots and lots of problems when learning engineering.
6	Disagree	After I study a topic in engineering and feel that I understand it, I have difficulty solving problems on the same topic.
7	Disagree	Knowledge in engineering consists of many disconnected topics.
8	N/A	As engineers learn more, most engineering ideas we use today are likely to be proven wrong.
9	Disagree	When I solve an engineering problem, I locate an equation that uses the variables given in the problem and plug in the values.
10	N/A	I find that reading the text in detail is a good way for me to learn engineering.
11	Disagree	There is usually only one correct approach to solving an engineering problem.
12	Agree	I am not satisfied until I understand why something works the way it does.
13	Disagree	I cannot learn engineering if the teacher does not explain things well in class.
14	Disagree	I do not expect engineering equations to help my understanding of the ideas; they are just for doing calculations.
15	Agree	I study engineering to learn knowledge that will be useful in my life outside of school.
16	Agree	If I get stuck on an engineering problem my first try, I usually try to figure out a different way that works.
17	Agree	Nearly everyone is capable of understanding engineering if they work at it.
18	Disagree	Understanding engineering basically means being able to recall something you've read or been shown.
19	Disagree	There could be two different correct values to an engineering problem if I use two different approaches.
20	Agree	To understand engineering, I discuss it with friends and other students.
21	Disagree	I do not spend more than five minutes stuck on an engineering problem before giving up or seeking help from someone else.
22	Disagree	If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally) to come up with it.
23	Disagree	If I want to apply a method used for solving one engineering problem to another problem, the problems must involve very similar situations.
24	Disagree	In doing an engineering problem, if my calculation gives a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem.
25	Agree	In engineering, it is important for me to make sense out of formulas before I can use them correctly.
26	Agree	I enjoy solving engineering problems.
27	Agree	In engineering, mathematical formulas express meaningful relationships among measurable quantities.
28	Disagree	It is important for the government to approve new scientific ideas before they can be widely accepted.
29	Agree	Learning engineering changes my ideas about how the world works.
30	Disagree	To learn engineering, I only need to memorize solutions to sample problems.
31	Agree	Reasoning skills used to understand engineering can be helpful to me in my everyday life.
32	Agree Only	We use this statement to discard the survey of people who are not reading the questions. Please select "Agree" for this
33	Disagree	Spending a lot of time understanding where formulas come from is a waste of time.
34	N/A	I find carefully analyzing only a few problems in detail is a good way for me to learn engineering.
35	Agree	I can usually Figure out a way to solve engineering problems.
36	Disagree	The subject of engineering has little relation to what I experience in the real world.
37	Agree	There are times I solve an engineering problem more than one way to help my understanding.
38	Agree	To understand engineering, I sometimes think about my personal experiences and relate them to the topic being analyzed.
39	Agree	It is possible to explain engineering ideas without mathematical formulas.
40	Agree	When I solve an engineering problem, I explicitly think about which engineering ideas apply to the problem.
41	Disagree	If I get stuck on an engineering problem, there is no chance I'll figure it out on my own.
42	N/A	It is possible for engineers to carefully perform the same experiment and get two very different results that are both correct.
43	Agree	When studying engineering, I relate the important information to what I already know rather than just memorizing it the way it is presented.

CLASS originally used a five-point Likert scale (strongly agree, agree, neutral, disagree to strongly disagree. CLASS for spring 2021 MEB used a modified Likert scale to eliminate the neutral response for this assessment in a similar manner to previous work [27, 28, 33]. The CLASS instrument was modified and validated for engineering-related content by two chemical engineering faculty for attitudes about engineering [28].

The expert opinion of the 9 animation-themed questions were selected by the author of this thesis, and subsequently validated by two University of Toledo faculty. All 9 questions had "agree" as the expert response (Table 3.2).

Table 3.2 - 9 Question animation-themed CLASS attitude list

Question Number	Expert Response	Statement
44	Agree	I am familiar with watching animation in movies (e.g., Disney, Pixar)
45	Agree	I am familiar with using or watching animation in slide presentations (e.g., PowerPoint, Google Slides)
46	Agree	I am familiar with using or watching animations in my university classes.
47	Agree	In engineering studies, it is helpful to know Adobe Suite (i.e., Adobe Flash, Adobe Photoshop)
48	Agree	Animation is a helpful medium to learn engineering concepts
49	Agree	Animation is a helpful medium to learn non-technical concepts (e.g., English, business, humanities)
50	Agree	In your university courses, animation helps my learning more than reading static text (e.g., standard textbook reading)
51	Agree	In your university courses, animation helps my learning more than using static figures (e.g., textbook graphs and tables)
52	Agree	In your university courses, animation helps my learning more than video recordings (e.g., pre-recorded lectures)

The 42 core CLASS questions and 9 additional animation-themed questions were administered through Microsoft Forms because the class was being offered only through remote delivery. The pre-survey was administered during the first 2 weeks of the semester, and the post-survey was administered during the last 2 weeks of the 15-week semester.

The attitudes about engineering and animations research questions are designed to measure the novice-to-expert progress of the students in an MEB course. This evaluation addresses two research questions. First, what are students' attitude about engineering studies? Second, what are students' attitudes about animations use in engineering education?

3.2 Results and Discussion

We will start by summarizing the CLASS results. The pre-survey participation was 61 of 78 enrolled students, however, 55 responses were included in the analysis due to incomplete responses. The post-survey participation was 58 of 63 enrolled students, however, 54 responses were included in the analysis due to incomplete responses.

Next, the survey responses presented here are aggregated, so no individual student data is relevant. Also, survey scoring combined strongly agree/agree and strongly disagree/disagree as single responses. Student response was compared to the expert response to yield a score for each response.

The first research question addresses students' attitude about engineering studies. Aggregating the 42 core questions of the CLASS, the pre-survey average score was 73.9%, and the post-survey average score was 75.2%. Thus, the survey indicated a small positive 1.3% shift, which was not found to be statistically significant (Table 3.3, $p = 0.52$). Comparing to an earlier study, engineering attitudes showed a 3% positive change between pre and post surveys in the same course [28]. The small positive changes in novice-to-expert attitudes after taking an engineering course related to material and energy balances may be due to the remote class delivery required during the COVID-19 pandemic.

Table 3.3 Comparison of CLASS results from the literature

Literature Source	Pre Semester, %	Post Semester, %	Shift, %	Normalized Gain, %	P(T<=t) two-tail	Course Content
Adams, 2006 [35]	62	53	-9.0	-15	Not reported	Physics I
Adams, 2006 [35]	57	59	2.0	3.5	Not reported	Physics II
De la Garza, 2010 [39]	68	71	3.1	4.5	0.056	Physics
Miner-Bolotin, 2011 [36]	65	59	-6.0	-9.2	Not reported	Introductory physics
Slaughter, 2012 [40]	70	73	3.0	4.3	0.24	First year physics
CHEE2010 2018 MEB [28]	78	81	3.0	3.8	0.18	Chemical Engineering MEB CHEE2010
Current research (CLASS)	74	75	1.3	1.8	0.52	UT MEB CHEE2010
Current research (animation questions)	83	84	1.0	1.2	0.82	UT MEB CHEE2010

The CLASS instrument, originally used for physics, has been modified previously, and results can be aggregated from other STEM disciplines in the literature (Table 3.3). Early use of CLASS in physics showed pre-semester expert agreement between 57% to 62% and post-semester results identified negative attitude shifts [35]. Subsequent use showed the pre-semester expert agreement increased to between 65 and 70% with p-values (Table 3.3) indicating no statistical significance [36, 40].

Next, how using an interactive textbook with over 100 animations affected students' attitudes about animations use in engineering education was explored. Aggregating the 9 animation-themed survey questions, the pre-survey average score was

83.3% and the post-survey average score was 84.4%. Thus, the survey indicated a small positive 1.0% shift, which was not found to be statistically significant (Table 3.3, p = 0.82).

Table 3.4 - 9 Question animation attitude-themed CLASS pre and post results

Animation Attitude Question Number	44	45	46	47	48	49	50	51	52
Start of Semester (SOS)	100.0%	92.7%	61.8%	92.7%	92.7%	76.4%	85.5%	78.2%	72.7%
End of Semester (EOS)	98.1%	94.4%	90.7%	92.6%	92.6%	75.9%	87.0%	85.2%	42.6%
Shift	-1.9%	1.7%	28.9%	-0.1%	-0.1%	-0.4%	1.6%	7.0%	-30.1%

3 of the 9 animation-themed survey questions returned changes > 5%, which warrants further discussion (Table 3.4). First, the animation question: I am familiar with using or watching animations in my university classes; identified a +29% shift. The experience with viewing over 140 MEB animations during the semester certainly supported a gain. The post-value of 91% correlates well with the high view rates reported earlier in this thesis.

Second, the animation question: In your university courses, animation helps my learning more than video recordings (e.g., pre-recorded lectures); identified a -30% shift. This result is of particular interest because the entire semester for MEB spring 2021 was held virtually through Microsoft Teams due to University of Toledo COVID-19 policy. Class time was recorded for student viewing anytime, however, the recorded classes were not widely viewed so the negative shift is not surprising. The post-survey value of 43% is surprisingly low when considering the high animation view rates.

Third, animation question: In your university courses, animation helps my learning more than using static figures (e.g., textbook graphs and tables); identified a +7% shift. Once again, viewing over 140 MEB animations during the semester certainly support a gain. Static figures and tables were used to a small extent, such as steam tables, making this a viable question. The 85% post-survey value supports animation and zyBook interactive textbook usage and aligns with high view rates reported earlier in this thesis.

A potential limitation of administering pre- and post-surveys is student incentive to participate. High survey participation may have been from presenting the survey's purpose and regular participation reminders.

3.3 Conclusions

Engineering attitude gains in MEB compared well to gains of similar studies. Specifically, a positive 1.3% shift was measured. The small improvement shift may be attributed to two possible reasons. First, the 2021 MEB enrollment, typically includes students who have declared a chemical engineering major indicated by a Pre CLASS score of 74% and Post of 76%, which are both higher scores than other studies cited. Second, the students may feel familiar and comfortable with engineering and problem solving skills from prerequisite classes supporting the higher Pre and Post CLASS scores.

Animation usage attitude measured a +1.0% shift aggregating the nine questions. First, the 2021 MEB enrollment is ten to fifteen years after the other studies using CLASS, and digital native students are familiar with animation as indicated by a Pre CLASS score of 83%. Second, the interactive textbook and zyBook animations became a familiar and comfortable learning platform while using the animations . Third, the -30% attitude shift related to Questions 52: In your university courses, animation helps my learning more than video recordings (e.g., pre-recorded lectures); does not align with the other observations and will require further study.

Chapter 4 Conclusions and Future Directions

Conclusions

Animation usage in the MEB zyBook revealed that low-stakes graded assignments encourage high reading participation. Student animation view rates near 100% and average student re-watch rate up to 10% support interactive textbook usage. Median animation view time by chapter ranged from 22 to 42 s, which is a reasonable duration to keep the attention of the students and match cognitive load. Animation characterization revealed that students spent more time on Derivation animations than other characterization types.

Normalized animation view time was not evaluated in this thesis due to data discrepancies. Normalization was initially considered to have the potential for revealing students dwell on animations views. The intention of dwell may be of interest to evaluate topics where students are spending time reflecting on the animation. Recommendations for future research should consider further clarification and validation of the minimum time for each animation by step as a benchmark.

CLASS Attitude about Animations in the MEB zyBook indicated small positive changes in novice-to-expert attitudes after taking an engineering course related to material and energy balances. The small gains of 1.3% for attitudes in engineering and 1.0% for attitudes about use of animations are not statistically significant. The agreement when averaging the 9 animation questions was > 80% which showed that digitally native students are familiar with animations.

Future Directions

View times data across the cohorts should be justified statistically in future research. Comparison of the statistical analysis as well as evaluating animation step time duration with other interactive textbooks may be valuable as a benchmark comparison. In addition, view durations by step for the first, second and third views by characterization and step count may identify key areas of difficulty or misconception. Similarly, future research of animation usage could consider evaluating the change in re-watch rate if low stakes re-watch graded assignments were offered.

Future view time research should evaluate the minimum view time for each step of each animation for normalization analysis. Normalized view of animation characterizations was considered for evaluation in this thesis by comparing minimum view time to actual student view time to attempt an evaluation of student reflection time. After reviewing the zyBook animation view time data there was additional validation of the minimum view time for each animation and the evaluation of normalized animation view was not able to be included in this thesis. Minimum view time analysis attempted to identify the minimum step time duration for each animation. Confirming minimum view time is recommended for future study in this area.

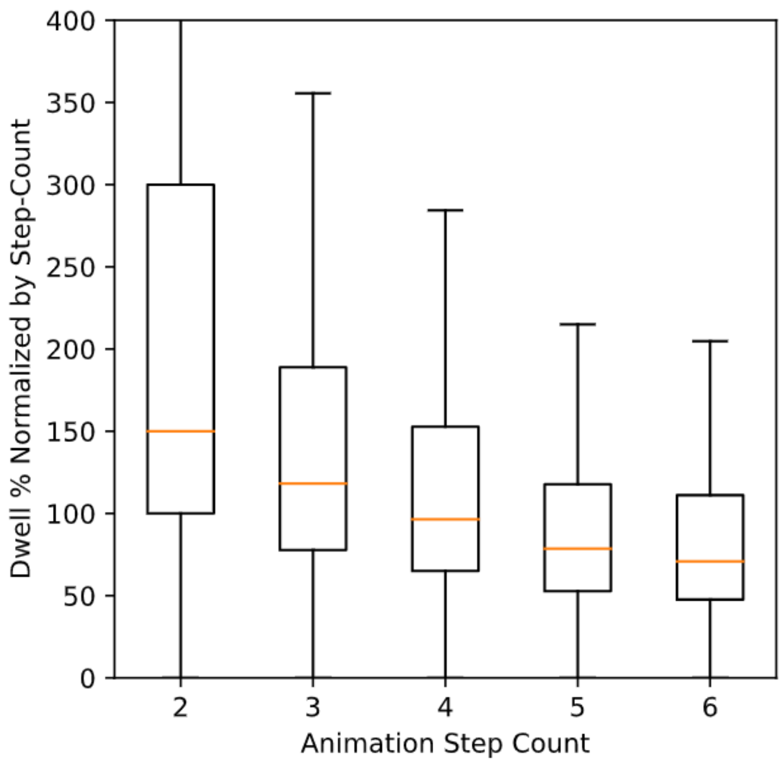

Figure 4.1 - Aggregate animation normalized view by time and step count

Minimum step time duration was used to calculate normalized view (Dwell %) by time and steps for evaluation in this thesis. The initial work on Dwell % however (Figure 4.1) generated a negative trend in the average aggregate dwell % with increased step count. While greater than 100% dwell is observed for 2-step and 3-step animations, the value declines to 80% dwell for 4-step animations, and 70% dwell for 5-step and 6-step animations. Also identified is the narrowing of the 3rd quartile with increasing as step count where upper and lower quartiles range for 2-step animation is 90% (160% to 70%) dwell, while upper and lower quartile for 5-step and 6-step animations is 45% (105% to 50%) dwell Plot (Figure 4.1). The dwell analysis is of interest because is indicates student interest in learning and reviewing animations. The results indicated that students spend less than minimum time on the animations, which is not correct based on formula parameters.

The work on normalized view is preliminary and presented to seed future work. At least two criteria should be considered. First, establishing the minimum animation view time by step requires review with the stepwise minima. Second, the normalized and double normalized view and % dwell objectives need evaluation to be a meaningful analysis of educational animations. The original intent was to evaluate animation duration, effect of the step count, and identify trends that would lead to improvements in animation use, which may guide instructors about challenging concepts. The purpose and objectives of normalized view need further definition for meaningful research.

Normalized view analysis is recommended for future research to compare minimum view time and actual student view time indicating student reflection time. After reviewing the view time data and finding some inconsistencies, additional validation of the minimum view time and evaluation of normalized animation view was not included in this thesis. Normalized View is defined as follows:

$$\text{Normalized View, \%} = \frac{\text{View Time}}{\text{Animation Minimum Time}} \text{ x } 100\%$$

Further research to re-administer the CLASS in MEB on a periodic basis may identify trends in student attitudes of digital natives. In addition, future research should consider discussing the purpose of CLASS and sharing previous results with MEB students for their understanding of CLASS importance. The 9 CLASS animation-themed questions require review, restatement for clarity, and expert responses re-validation to remove confusion and the repeated positive responses to the questions. Distinguishing between comparing single items (e.g., animation vs figure) and all items in a category (e.g. all animations in the book vs all video lecturers for a semester) may clarify some of the 2021 cohort’s responses.

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Appendix

Appendix A-1: MEB Course Table of Contents

Figure A-1 zyBook CHEE2010 MEB Course – Table of Contents. The MEB interactive textbook table of contents identifies the course topics.

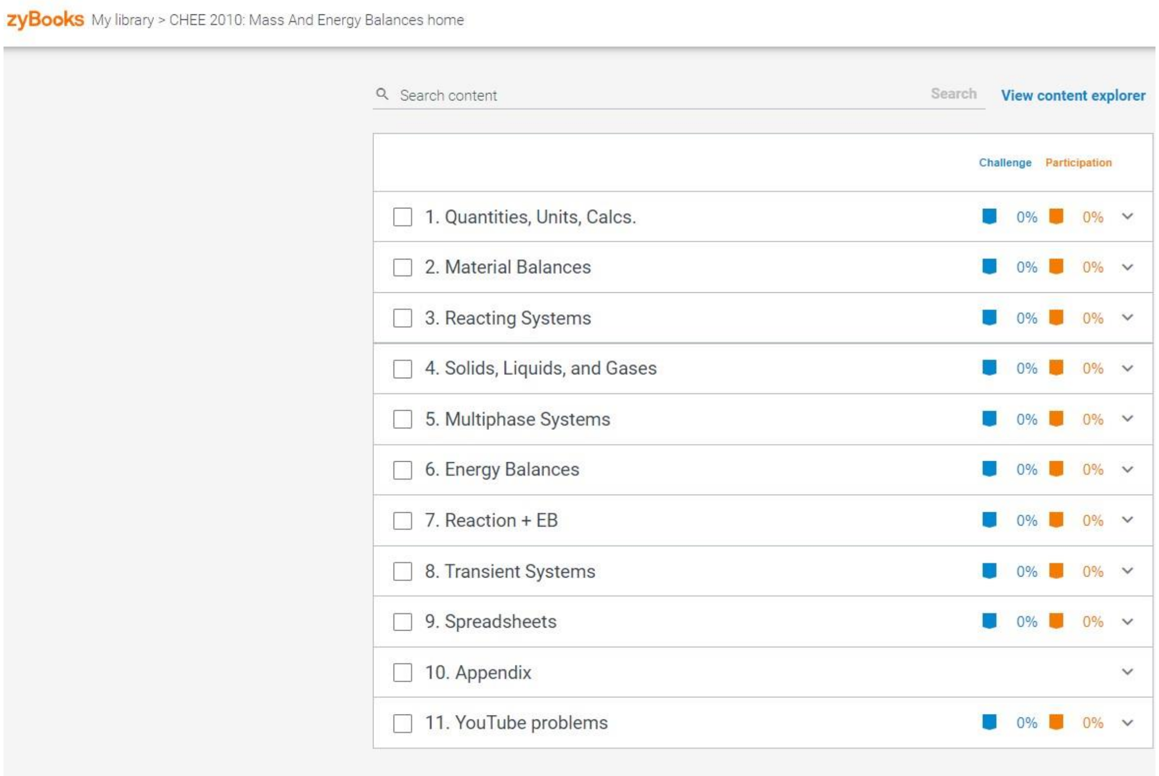

Figure A-1 zyBook CHEE2010 MEB Course – Table of Contents

Appendix A-2: MEB Course Raw Data Format

Figure A-2 zyBook CHEE2010 MEB Course – Raw Data Format. This Appendix presents the format of the raw as-received zyBook Participation Activity data. This data is the basis for the animation analysis and preparing the results of this thesis.

	A	B	C	D	E
1	resource_id	timestamp	user_id	complete	metadata
2	32560510	1/14/2019 18:46	431278	0	{\event\":\"start clicked.\"}"
3	32560510	1/14/2019 18:46	431278	0	{\event\":\"step 0 clicked.\"}"
4	32560510	1/14/2019 18:47	431278	0	{\event\":\"Play button clicked. Step 5 started.\"}"
5	32560510	1/14/2019 18:47	431278	0	{\event\":\"Play button clicked. Step 6 started.\"}"
6	32560510	1/14/2019 18:49	431278	0	{\event\":\"start clicked.\"}"
7	32560510	1/14/2019 18:50	431278	0	{\event\":\"Play button clicked. Step 2 started.\"}"
8	32560510	1/14/2019 18:50	431278	0	{\event\":\"Play button clicked. Step 3 started.\"}"
9	32560510	1/14/2019 18:50	431278	0	{\event\":\"Play button clicked. Step 4 started.\"}"
10	32560510	1/14/2019 18:50	431278	0	{\event\":\"Play button clicked. Step 5 started.\"}"
11	32560510	1/14/2019 18:50	431278	0	{\event\":\"Play button clicked. Step 6 started.\"}"
12	32560510	1/14/2019 18:50	431278	1	{\event\":\"animation completely watched\"}"
13	32560510	1/14/2019 19:24	431318	0	{\event\":\"start clicked.\"}"
14	32560510	1/14/2019 19:24	431318	0	{\event\":\"Play button clicked. Step 2 started.\"}"
15	32560510	1/14/2019 19:24	431318	0	{\event\":\"Play button clicked. Step 3 started.\"}"
16	32560510	1/14/2019 19:24	431318	0	{\event\":\"Play button clicked. Step 4 started.\"}"
17	32560510	1/14/2019 19:24	431318	0	{\event\":\"Play button clicked. Step 5 started.\"}"
18	32560510	1/14/2019 19:24	431318	0	{\event\":\"Play button clicked. Step 6 started.\"}"
19	32560510	1/14/2019 19:24	431318	1	{\event\":\"animation completely watched\"}"
20	32560510	1/14/2019 22:31	432700	0	{\event\":\"start clicked.\"}"
21	32560510	1/14/2019 22:32	432700	0	{\event\":\"go to start clicked.\"}"
22	32560510	1/14/2019 22:32	432700	0	{\event\":\"start clicked.\"}"
23	32560510	1/14/2019 22:32	432700	0	{\event\":\"step 0 clicked.\"}"
24	32560510	1/14/2019 22:32	432700	0	{\event\":\"Play button clicked.\"}"
25	32560510	1/14/2019 22:33	432588	0	{\event\":\"start clicked.\"}"

Appendix A-2 Figure - Format of 2019 raw zyBook animation view data in the .csv file

The description of the columns shown in Appendix B Figure are as follows:

Column A - Resource ID, the MEB zyBook animation identification number

Column B – Time Stamp for event log

Column C - User ID, student identification to log activity (for auto grading assignments)

Column D – click log of initiation or completion of animation

Column E – event activity description

Appendix A-3: MEB Animation Examples (completed displays)

This Appendix presents examples of completed zyBook animations identifying the four of the five characterizations (C, D, FP, PW, SS) and step counts as noted in the captions.

Note: 4 step example animation is presented in Appendix A-4.

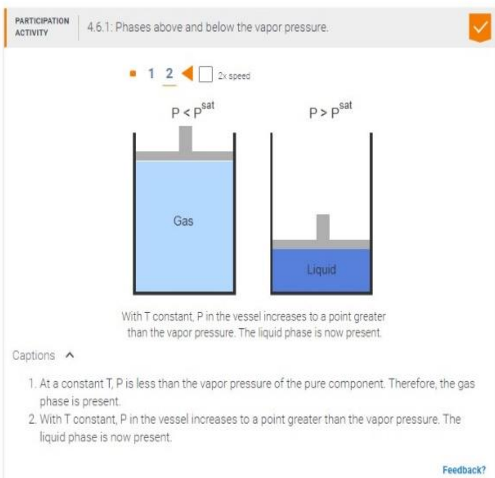

Figure A-3.1 Concept Animation (C) 2-step example

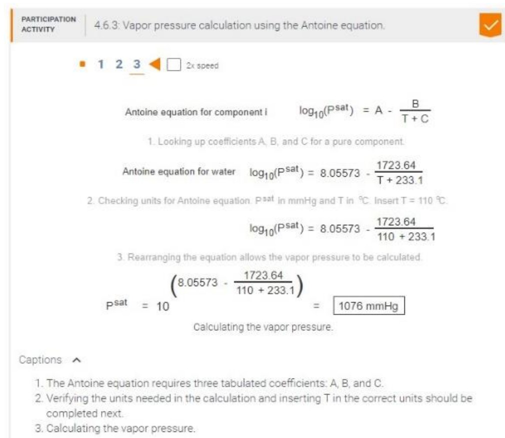

Figure A-3.2 Derivation Animation (D) 3-step example

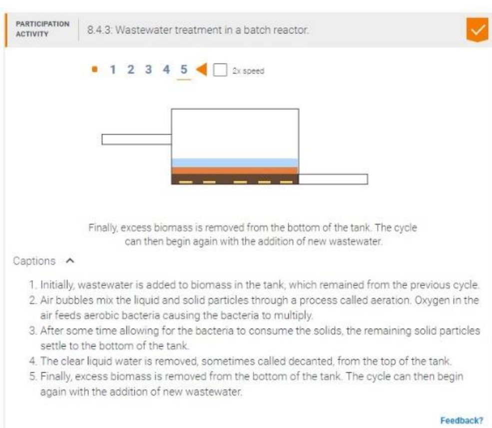

Figure A-3.3 Physical World Animation

(PW) 5-step example

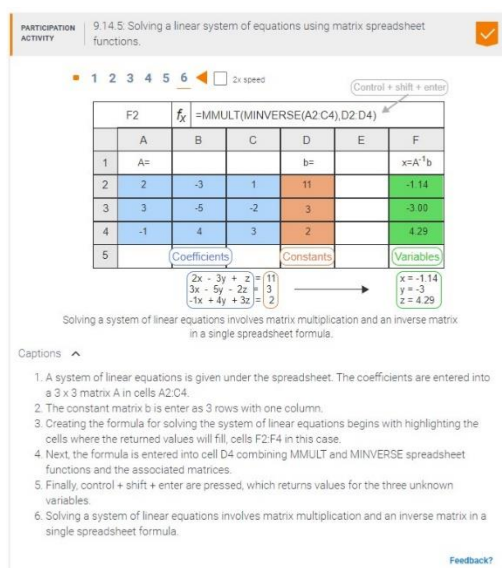

Figure A-3.4 Spreadsheet Animation (SS) 6-step example

Appendix A-4: MEB Figures & Plots Animation (FP) All Steps Example

Figures A-4.1 through A-4.5 ....zyBook CHEE2010 MEB Course Figures & Plots Animation (FP) Example. This Appendix presents all **four** steps of zyBook Participation Activity 5.3.1, Finding bubble and dew points on a P-xy diagram (zyBook caption). Figures & Plots Animation (FP) dynamically presents information in table, chart, figure, or list format.

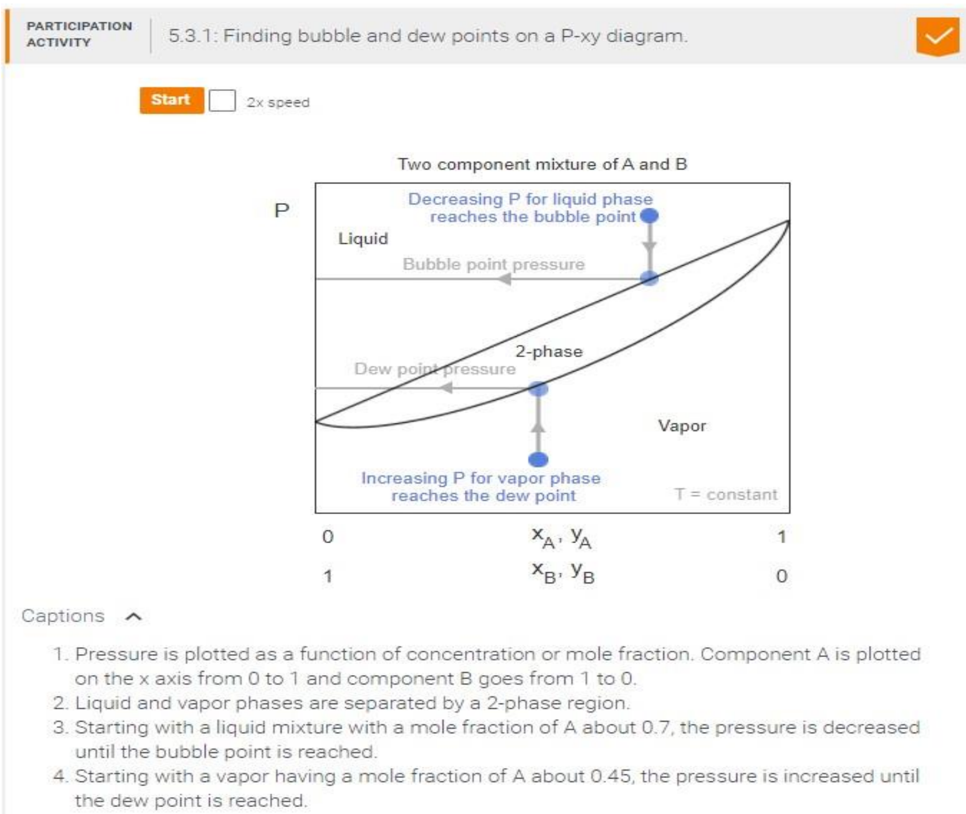

Figure A-4.1 Figures & Plots Animation (FP) Example

Initial Static Image: Animation 5.3.1, Finding bubble and dew points on a P-xy diagram

Figure A-4.2 Figures & Plots Animation (FP) Example. The animation sequence proceeds until the arrow to the right of the step numbers appears with Step 1 completion (Figure A-4.2).

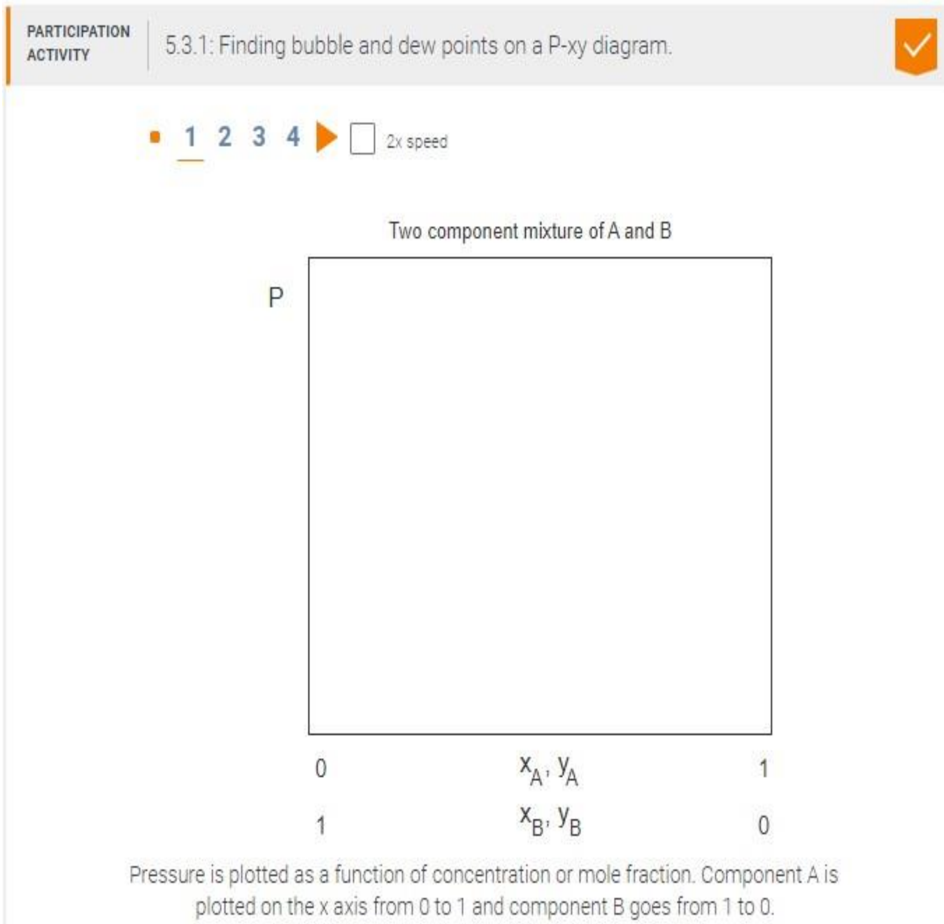

Figure A-4.2 Figures & Plots Animation (FP) Example

<u>Completed Step 1:</u> Animation 5.3.1, Finding bubble and dew points on a P-xy diagram

Figure A-4.3 Figures & Plots Animation (FP) Example. Clicking the sequence arrow continues the animation and builds on the previous steps to completion. (Figure A-4.3).

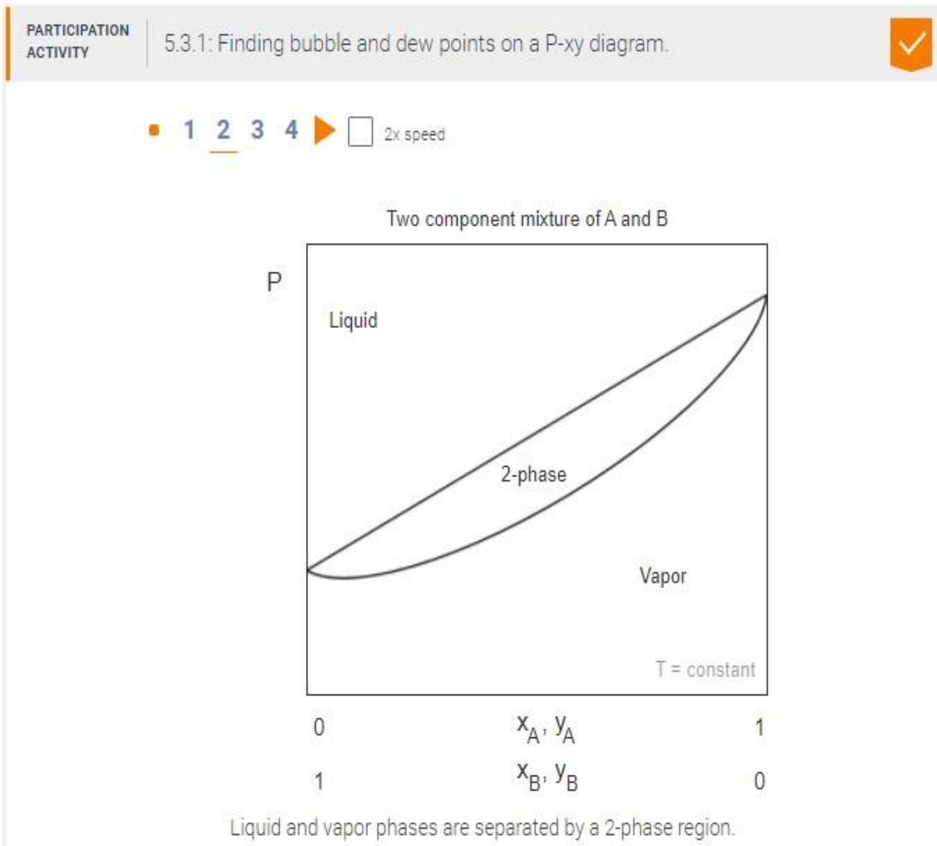

Figure A-4.3 Figures & Plots Animation (FP) Example

<u>Completed Step 2:</u> Animation 5.3.1, Finding bubble and dew points on a P-xy diagram

Figure A-4.4 Figures & Plots Animation (FP) Example. The animation sequence proceeds until the arrow to the right of the step numbers appears at Step 3 completion (Figure A-4.4).

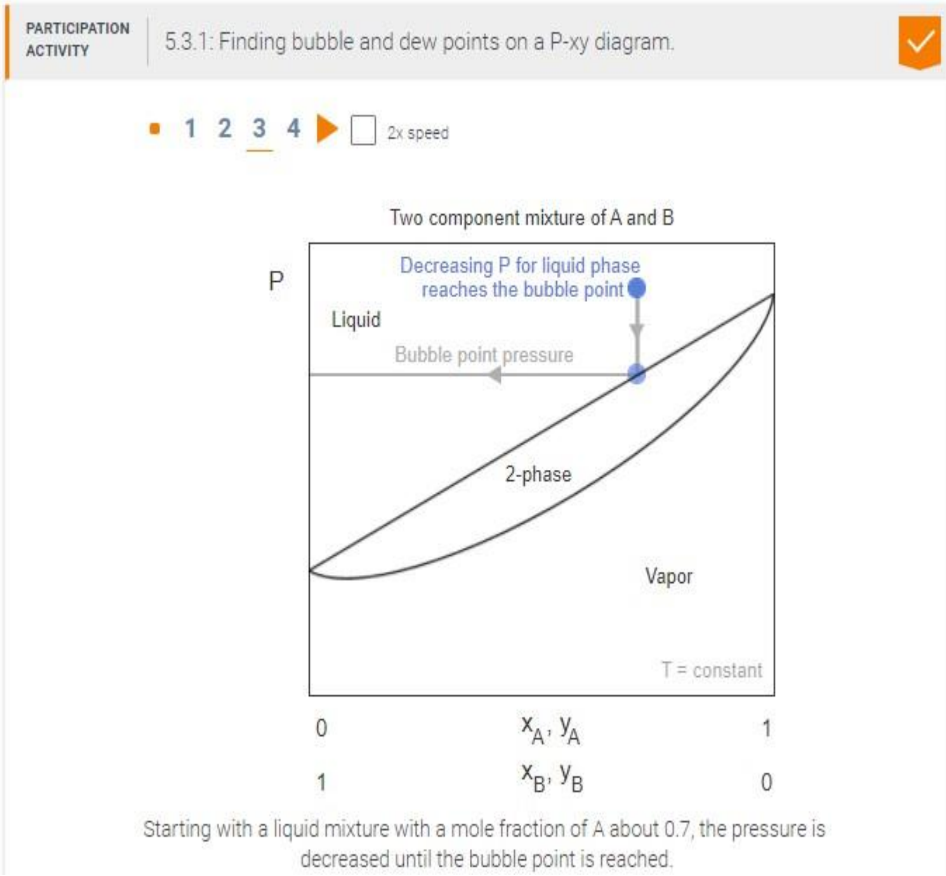

Figure A-4.4 Figures & Plots Animation (FP) Example

<u>Completed Step 3:</u> Animation 5.3.1, Finding bubble and dew points on a P-xy diagram

Figure A-4.5 Figures & Plots Animation (FP) Example. The completed animation Step 4 displays the initial static image of the animation and a completed view is recorded (Figure A-4.5).

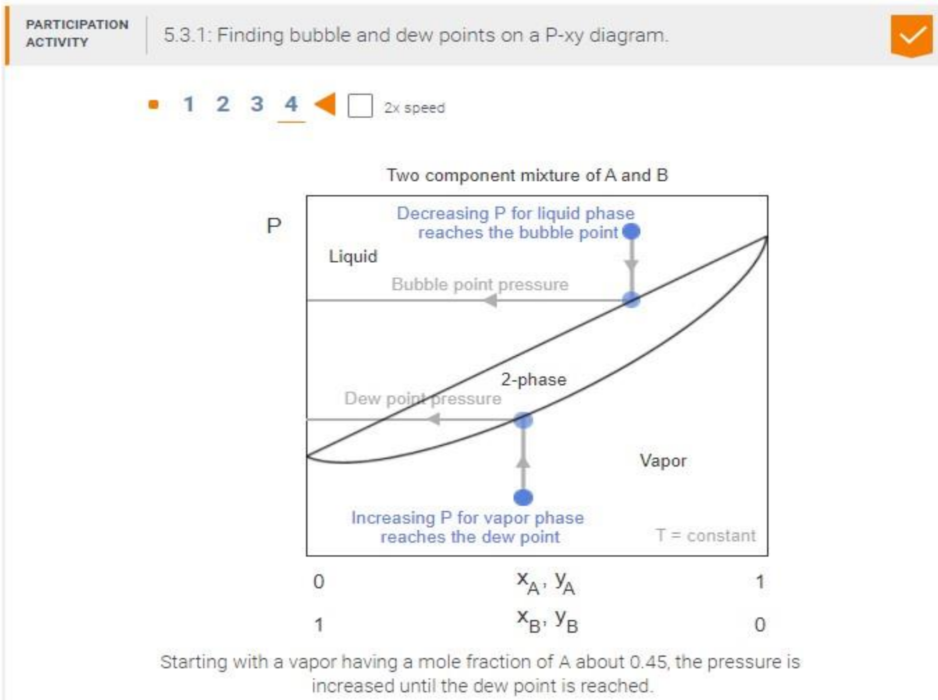

Figure A-4.5 Figures & Plots Animation (FP) Example

Completed Step 4: Animation 5.3.1, Finding bubble and dew points on a P-xy diagram

Confirmation of Step 4 completion is observed with the sequence arrow being reversed at the top of the animation and the figures restored to the original state. Confirmation that the student has completed viewing the animation is verified with the check mark in the orange box at the upper right of the animation.