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Frustration in technology-rich learning environments: A scale for assessing student frustration with e-textbooks

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Abstract

e-Textbooks and e-learning technologies have become ubiquitous in college and university courses as faculty seek out ways to provide more engaging, flexible and customizable learning opportunities for students. However, the same technologies that support learning can serve as a source of frustration. Research on frustration with technology is limited, especially in educational settings. This study examined student frustration with e-textbooks and the factors contributing to the frustration within undergraduate general biology courses through the development of an E-Text Frustration scale (ETFS). Exploratory factor analysis of the ETFS revealed a three-factor structure that provides quantified support for frustration with (1) e-textbook interactions on the screen, (2) problems with technology and (3) e-text curriculum integration. This structure was supported by a confirmatory factor analysis. The construct validity of the scale was established using a correlation analysis that revealed significant relationships among the three e-text frustration measures, cognitive load and motivation variables. Furthermore, the measurement invariance analyses indicated that the scale measures the same construct in the same way in males and females. Overall, the study findings suggest that

the ETFS is a useful instrument with high reliability and validity evidence that can be used by researchers and practitioners. Implications for future research on frustration in technology-rich learning environments are discussed.

KEYWORDS
cognitive load, digital textbooks, e-learning technologies, frustration, motivation, scale development

Practitioner notes

What is already known about this topic
- Prolonged student frustration can be harmful to learning.
- Educational technology may introduce an additional layer of factors that contribute to end-user frustration with technology.
- Research on frustration with educational technology is scarce.

What this paper adds
- We developed and validated a scale for assessing students' frustration with e-textbooks.
- The *E-Text Frustration* scale includes three factors: frustration with technology, e-text screen interactions and e-text curriculum.
- The three factors correlated with students' e-text cognitive load and motivation to learn.

Implications for practice and/or policy
- The identified factors represent barriers to students' successful learning with e-textbooks.
- Educators can reduce student frustration by aligning the curriculum with e-text materials.
- Student sources of frustration with technology should be studied systematically to reduce frustration in technology-rich learning environments.

INTRODUCTION

As the use of technology rapidly expands, so does user frustration (Ceaparu et al., 2004). Frustration is viewed as an 'emotional or pre-emotional response to unexpected obstacles impeding goal achievement' (Bessière et al., 2006, p. 942). User frustration is an emotional outcome associated with negative computing experiences (Bessière et al., 2006). Feelings of frustration manifest when computers and networks crash, there are poor network connections, errors occur (when the wrong password is entered or error messages are unclear) or when network delays ensue (Ceaparu et al., 2004; Ceapuaru & Shneiderman, 2003; Lazar & Huang, 2003; Lazar & Norcio, 2000). Much of the research in frustration with technology aims to reduce or mitigate negative experiences of end-users with poorly designed human–computer interfaces and computers (Baecker et al., 2000; Jeon, 2017; Opoku-Boateng, 2017). Frustration with technology can lead to a variety of negative

outcomes, including the discontinued use of technology, resistance behaviours (Beaudry & Pinsonneault, 2010; Stein et al., 2015; Wirth et al., 2015), poor morale in the workplace, slow learning, disruption in the work environment and poor satisfaction and self-efficacy (Lazar et al., 2006).

Literature on user affect categorizes prolonged frustration among negative emotions that are harmful to learning (D'Mello, 2017). A vast majority of research in this field investigated frustration at the general level of negative emotions, alongside anger, boredom and confusion, without focusing solely on frustration and its sources (eg, Harley et al., 2015; Spann et al., 2019). Although frustration is recognized as a problem, targeted research on frustration in educational settings, particularly with using e-texts and reading text on a screen is scarce. Research on user frustration in the workplace focused primarily on technological issues underpinning user frustration. Using technology for educational purposes may introduce an additional layer of factors that contribute to frustration. For instance, Lazar et al. (2006) showed that students in an educational setting and employees in the workplace demonstrated differences in how they experienced frustration. These findings indicate that a more focused research approach is needed to understand and measure frustration with technology. To address the gap, this study examined perceived student frustration with electronic textbooks (e-texts) in undergraduate biology courses and the factors that contributed to it. In addition, it examined the relationships among students' e-text frustration, cognitive load (CL) and motivation—factors that are known to influence learning with technology. In this context, we view frustration as an emotional or pre-emotional response to unexpected obstacles impeding learning with e-texts.

LITERATURE REVIEW

Frustration with technology

Frustration has multiple implications for learning with technology. According to research on goal theory (Locke & Latham, 1990), goal commitment directly affects human performance. Moreover, the individual response to blocks or obstacles impeding their goal depends on the level of their goal commitment and the importance of the goal (Bessière et al., 2006) as well as the complexity of the learning material (Holzinger et al., 2008). For instance, a student who needs to finish a chapter an evening before the test will likely become frustrated if technological issues impede their access to the e-text. Moreover, research on information processing (Markus, 1990) indicates that frustration redirects 'limited attentional resources away from the central task or goal at hand to peripheral features of the information environment that may now have become obstacles' (Bessière et al., 2006, p. 944). Most of these processes happen unconsciously. Thus, when a student cannot access a quiz or simulation on their e-text or it fails to scroll on a screen, it requires their immediate attention and redirection of cognitive resources to resolve these issues. Therefore, if frustration is the result of a block in the path towards successful e-text learning, then it is important to examine the factors that influence the level of frustration experienced by a student (Boehner, 2007; Klein et al., 2002; Opoku-Boateng, 2017). Identifying these factors can help remove barriers to learning with e-texts.

Cognitive load

CL theory (Sweller, 2010; Chandler & Sweller, 1991) is considered among the major frameworks in educational research for evaluating learning environments (Klepsch et al., 2017).

According to CL theory, the human cognitive system should be considered when designing learning materials and instruction, as working memory capacity is closely related to information processing (Leppink et al., 2014; Sweller, 2010; Van Merriënboer & Sweller, 2005). CL theory distinguishes between intrinsic and extraneous CL (Sweller, 2010; Sweller et al., 1998). Intrinsic CL is determined by an individual's prior knowledge and task complexity. Thus, if students do not have adequate prior knowledge or the e-text learning task is too difficult or too easy, it can contribute to student e-text frustration. Extraneous CL is determined by instructional features and tasks that are not beneficial to learning. For example, suboptimal learning materials are one of the extensively researched sources of extraneous load (Mayer, 2014). Thus, both frustration and extraneous CL relate to information processing, as they involve processes that require the redirection of an individual's cognitive resources to activities that are extraneous to learning, thus inhibiting the learning process (Markus, 1990; Sweller, 2010). Recent research shows that poorly designed e-learning materials, troubleshooting technical issues, reading from a screen, or navigating and manipulating e-texts can be sources of both frustration and extraneous CL (Novak et al., 2018a).

Learning motivation

Learning motivation refers to student desire, choice and commitment to learn (Keller, 2010). It explains what goals learners choose to pursue and the magnitude of these efforts. There are a variety of factors that affect learners' motivation to overcome obstacles in order to attain their goals. Keller (1999, 2008) classified these factors into five clusters of related motivational theories and concepts: (1) attention, (2) relevance, (3) confidence, (4) satisfaction and (5) volition and self-regulation. Based on this classification, he developed five principles of motivation to learn (2008):

1. 'Motivation to learn is promoted when a learner's curiosity is aroused due to a perceived gap in current knowledge' (Keller, 2008, p. 176). This principle pertains to the attention category that encompasses research on curiosity, arousal and boredom (Berlyne, 1965; Kopp, 1982). It emphasizes the importance of gaining a learner's attention by building curiosity, promoting active engagement in the learning process and using a variety of different instructional approaches and learning activities to sustain attention. For instance, e-texts that include a well-designed interface and variety of learning tasks and activities (eg, adaptive content, videos, simulations) are likely to build curiosity and stimulate a sense of inquiry.
2. 'Motivation to learn is promoted when the knowledge to be learned is perceived to be meaningfully related to a learner's goals' (Keller, 2008, p. 177). This principle pertains to the relevance category that focuses on the importance of providing students with personally relevant learning materials. It stipulates that motivation to learn is promoted when learners are self-determined (Deci & Ryan, 1985) and experience intrinsic goal orientation due to engaging in personally interesting and meaningful activities. For example, if a student's goal is to successfully pass a course, then the student is more likely to be motivated to learn with an e-text that has a clear connection to specific learning goals stated in the course syllabus.
3. 'Motivation to learn is promoted when learners believe they can succeed in mastering the learning task' (Keller, 2008, p. 177). This principle pertains to the confidence category that includes research on self-efficacy (Bandura, 1977), attribution theory (Weiner, 1974), self-determination theory and goal orientation theory (Dweck & Leggett, 1988; Nicholls, 1984). People are more motivated to learn when they have positive expectations for success and

feel confident that they can experience success because of their own efforts and abilities rather than external factors that they cannot control. Therefore, students are more likely to be motivated to learn with an e-text when there is an expectation of success within the course.

4. 'Motivation to learn is promoted when learners anticipate and experience satisfying outcomes to a learning task' (Keller, 2008, p. 177). This principle pertains to satisfaction with the learning process. When people are satisfied with their learning, they feel more motivated to continue to learn. For example, students who are satisfied with their e-text learning are more likely to continue using e-texts in the future.

5. 'Motivation to learn is promoted and maintained when learners employ volitional (self-regulatory) strategies to protect their intentions' (Keller, 2008, p. 178). The first four categories refer to conditions that are necessary for students to become motivated. However, when various distractions, competing goals or obstacles interfere with one's persistence to achieve their goals, volitional strategies of self-control are necessary to stay on task. Therefore, students are more likely to be motivated to learn with an e-text when the processes that are extraneous to learning, such as network troubleshooting or technical difficulties, are minimized.

Integration of e-textbooks in K-12 and higher education

At their cores, institutes of higher education desire to promote student learning by increasing cognitive engagement where students think and reflect deeply (Llin, 2021; Lei et al., 2018; Sung et al., 2019). e-Texts provide opportunities to work with learning resources to gain new information and promote achievement (Lee & Koszalka, 2016; Sung et al., 2019; Wilhelm-Chapin & Koszalla, 2020). Modern e-texts make content delivery more engaging, flexible and customizable by offering a variety of learning experiences, including interactive tutorials, instructional videos, simulations, quizzes and adaptive learning platforms (Abaci et al., 2015; Tuah et al., 2019). In addition, the cost of e-texts is typically lower than printed versions (Baum et al., 2012). Because of these advantages, many institutions of higher education have adopted e-texts by integrating them directly into learning management systems to provide students with new and diversified learning opportunities and first-day access to materials (Chapman et al., 2016; Dennis, 2011).

Despite the growing availability of e-texts and the multitude of available learning tools, the acceptance of e-texts is slower than was predicted in K-12 and post-secondary settings (Mizrachi et al., 2021). According to the world's largest study of reading format preferences and behaviours in tertiary students (Mizrachi at el., 2021), majorities of students from 33 countries prefer print over e-text for academic readings. There are numerous reasons that influence students' preferences for print materials. For example, many respondents report problems or fatigue reading information from a computer/tablet screen while others find e-texts complicated to read and comprehend (Pihlstrøm, 2020; Rockinson-Szapkiw et al., 2013). Interestingly, the same factors that are reported as appealing about e-texts, such as the ability to search and annotate, and the rich multimedia content, can also serve as distractions for students diminishing the effectiveness of their learning (Johnston & Salaz, 2019; Ross et al., 2017). The ability to multitask, such as searching for keywords while watching a video and scrolling at the same time, can interfere with the focus needed to learn. Moreover, e-text preferences can be influenced by a student's experience reading research papers and complex texts (Li et al., 2011), the importance of a learning task to the student (Mizrachi, 2015), as well as the subject and academic discipline (Alfiras & Bojiah, 2020). Most of the research on e-texts has been conducted within individual classes or in laboratory settings. Large-scale e-textbook initiatives that

promote intentional, coordinated and sustained change in K-12 and higher education have seldom been reported in the literature. This study was conducted as part of a large-scale e-text initiative implemented in a biology department of a public university in the United States to examine student perceptions of e-text and e-text efficacy. Concerned about rising textbook costs for students, particularly in the sciences, a department of biology at a public university in the United States required students enrolled in 100 and 200-level courses to adopt e-texts that were administered through the learning management system (Blackboard) giving students first-day access to materials. In addition to reduced cost, the e-text offered access to online homework assignments, simulations, quizzes, animations and adaptive learning.

Goals of study

The goal of this research was to empirically examine perceived student frustration with e-texts in undergraduate general biology courses. We explored students' e-text experiences that are driven by individual goals over the period of a semester in order to develop a broad understanding of the various factors contributing to students' e-text frustration. In this study, an 11-item *E-Text Frustration* scale was developed based on a qualitative study conducted in a previous academic semester that sought to understand general student concerns with e-texts within these general biology courses. The specific goals of this study were to:

1. Present the development of the *E-Text Frustration Scale* (*ETFS*) and validate it using exploratory factor analysis (EFA) and confirmatory factor analysis (CFA).
2. Investigate the comparability of the ETFS' factors in male and female participants.
3. Examine the construct validity of the scale by correlating it and its factors with students' CL and motivation measures with the following two working hypotheses:

> *Research Hypothesis 3.1*: Student e-text frustration will positively relate to CL associated with using e-texts.

> *Research Hypothesis 3.2*: Student e-text frustration will negatively correlate with student motivation associated with using e-texts.

METHOD

A sequential qualitative–quantitative mixed analysis (Onwuegbuzie et al., 2010), with the qualitative data analysis informing the quantitative phase, was used to develop and validate the ETFS. We conducted two studies that took place over two consecutive academic semesters. The first study collected and analysed data from open-ended questions from a self-administered survey of undergraduate biology students to identify possible sources of student frustration with e-texts and develop ETFS' items. This approach ensures that 'the voices of key informants, which include those on whom the instrument will be administered, are heard, with a view to understanding their cultural milieu' (Onwuegbuzie et al., 2010, p. 63), and has been applied for scale development elsewhere (eg, Royalty et al., 2014). The second study took place in the following semester, when students rated their e-text frustration using the ETFS.

Study I: e-Text frustration scale development

This study was conducted at a public, comprehensive university in the southeastern United States. The first semester of this study, we administered an online anonymous survey to 1121 students enrolled in 100 and 200-level general biology courses and human anatomy and physiology laboratory courses that used e-texts. These courses comprised both majors and non-major classes and laboratories and included Human Anatomy and Physiology lecture and laboratory, Advanced Human Anatomy and Physiology lecture and laboratory, and General Biology courses for Biology majors and non-majors. These courses fulfilled a natural sciences general education elective at this university and some of these courses are required for certain majors with science and health fields. Many are gateway courses that allow students to progress into discipline specific, upper division classes.

Students used McGraw-Hill LearnSmart, SmartBook, E-text and Connect. These learning tools connected e-texts with relevant exercises, simulations and self-assessments, providing a customizable learning environment that tailored content to individual student needs (Figures 1 and 2).

The use of all the features of the e-text varied by course and instructor. Instructors teaching anatomy courses robustly used many features of the e-text including virtual dissections, animations, practice assignments/homework and digital atlases. Instructors in these classes took advantage of the adaptive learning metrics and metacognitive data collected by the vendor to gauge student learning and inform instruction. A couple instructors in other courses, who had not previously used digital resources, had a steeper learning curve for e-text implementation. Training provided by the vendor eased anxiety, but digital-novice faculty used the features of the e-text more cautiously. In all, faculty reported a positive response to the use of e-text and digital materials and the adoption moved some 'old school' faculty into the digital age (Garrison et al., 2015).

A link to the anonymous survey was posted in the university's learning management system at the end of the semester by professors' teaching sections of these courses. Participation
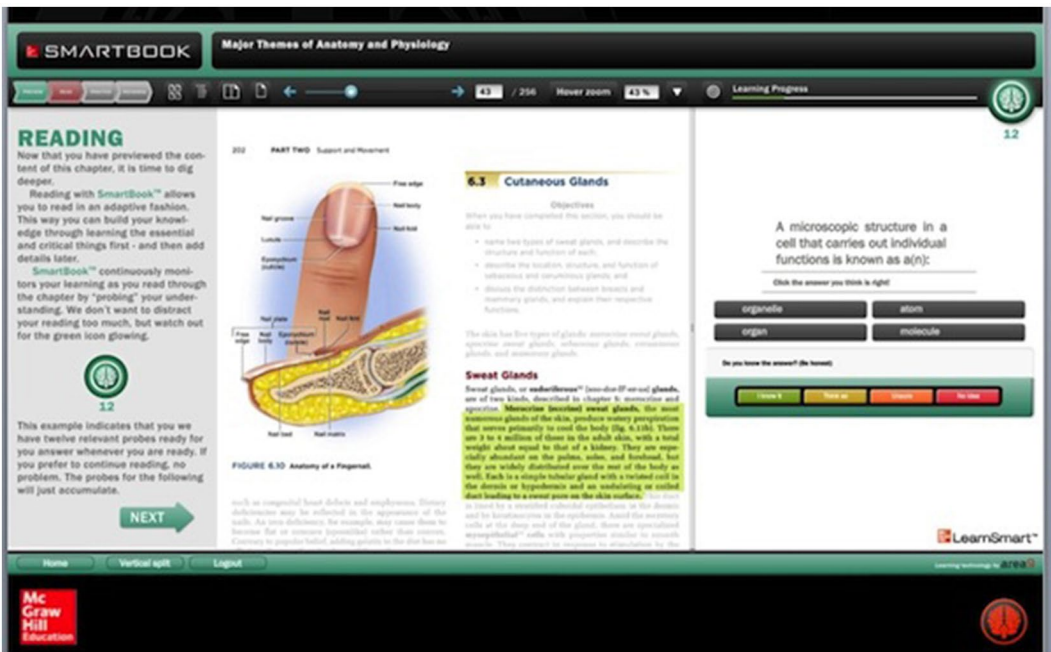

FIGURE 1 A screenshot of LearnSmart and Smartbook interactive learning modules
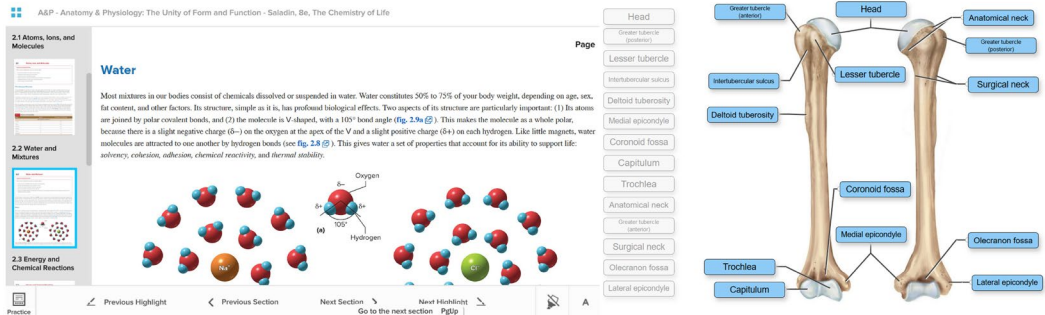
FIGURE 2 Sample screenshots of McGraw-Hill e-text and connect learning environments

was voluntary, and professors had the discretion of offering a small amount of extra credit to students for completing the questionnaire. The study was approved by the university's Institutional Review Board and participants were asked to electronically sign an informed consent document before viewing the survey instrument and participating in the study.

This survey included two open-ended questions that asked students about what they liked or disliked about using e-texts in their biology classes. We received 1073 student comments on what they liked and 1065 comments on what they disliked about their e-texts and their e-text experiences throughout the semester. To better understand possible sources of frustration with e-texts as well as e-text desirable features, the data were analysed independently by two co-authors not affiliated with the Department of Biology using constant comparative analysis (Glaser & Strauss, 1967). These two co-authors reviewed the emerging themes and collaboratively identified the following eight categories related to frustration with e-texts:

- e-textbook use (eg, navigation, search, highlighting, bookmarking)
- reading from a screen
- technical issues (eg, operating system problems, technical glitches, hardware problems)
- Internet access
- timely access to laptop or tablet to view the e-text content
- e-text usability on mobile devices
- lack of instructional alignment between the e-text content and course materials
- other problems

The emerging themes suggested a few key indicators that contributed to students' frustration with e-texts: technical issues that are common to any type of technology, accessibility issues, issues related to interactions with e-texts and pedagogical issues related to the use and integration of e-texts into the course curriculum. Once the key e-text frustration indicators were clearly articulated, we started generating a pool of items to measure these common concerns and problems. From this work we developed eleven 7-point Likert-type items for the ETFS (Table 1).

The desirable e-text features included:

- Portability: Students mentioned that e-texts gave them time to learn outside the class and they did not have to carry around a book.
- Built-in assessments: LearnSmart adaptive activities and self-tests/quizzes were linked directly to relevant text sections, thus allowing students to compare their quiz answers with the text.

T A B L E 1   e-Text frustration scale item descriptive statistics

#	Items	EFA ($n = 328$)		CFA ($n = 322$)	
		M	SD	*M*	SD
F1	Highlighting, bookmarking and personalizing e-texts	3.40	1.91	3.37	2.03
F2	Navigating and searching e-text content	3.66	1.85	3.61	1.96
F3	Technical issues and software glitches	3.51	1.90	3.41	2.04
F4	Limited or no Wi-Fi access	3.88	2.10	3.55	2.09
F5	Limited access to laptop or tablet to view the e-text content	3.11	1.98	3.71	1.90
F6	Limited usability on mobile devices	3.79	2.13	3.52	2.08
F7	Reading from a screen	3.88	2.11	3.61	2.18
F8	Lack of physical structure of the content like in print materials	3.89	1.95	3.74	2.17
F9	E-text content is not aligned with course curriculum	2.96	1.86	2.83	1.99
F10	No syllabus for online assignments	2.57	1.76	2.37	1.70
F11	Course instructor did not reference the e-texts	2.60	1.82	2.63	1.91

Abbreviations: CFA, confirmatory factor analysis sample; EFA, exploratory factor analysis sample.

- Availability of videos, simulations, animations and virtual experiences such as Anatomy & Physiology Revealed (a virtual cadaver dissection tool).
- Well-designed interface and visuals: Pre-highlighted text for the most important information, high-quality visuals (graphs, diagrams, tables).
- Easy navigation: Students mentioned that it was easy to find the necessary information.
- Novelty and interactivity.

Study II: Examining the structure of the e-text frustration latent variable

Participants

For the second study, we invited 1830 undergraduate biology students enrolled in the same 100 and 200-level courses to participate. A total of 896 students completed the online questionnaire at the end of the semester, yielding a participation rate of 48.9%. The mean age among participants was 20.49 years (SD = 2.92) and 71.8% were female. Approximately 76% had used e-texts in previous classes and 21.3% were repeating the course due to a previous course withdrawal or unsatisfactory grade.

Procedures

A link to this second online survey instrument was posted in the university's learning management system by professors teaching sections of these courses at the end of the semester. The online survey included questions related to demographic information (such as age, gender, major, prior e-text use, etc.), e-text frustration, CL, motivation and students'

preferences and attitudes. This voluntary survey was not limited in time, and professors had the discretion to award extra credit for student participation.

Instruments

e-Text frustration

Perceived frustration was measured using the 11-item ETFS developed in the prior semester (Study I). Respondents were asked to 'consider each of the following issues associated with the use of e-texts in the course and indicate how frustrated [they] were with the following e-text issues on a scale from 1 to 7, with 1 being "Not frustrating at all" and 7 being "Very frustrating"'.

e-Text CL questionnaire (Novak et al., 2018a; Cronbach's α = 0.859)

This questionnaire was derived from Leppink et al. (2014) questionnaire to assess students' intrinsic and extraneous CL associated with e-texts. The E-Text CL questionnaire (Appendix A) included nine Likert-type items with response choices ranging from 0 (not at all) to 10 (completely the case) that loaded on two subscales: intrinsic CL (the first four items; Cronbach's α = 0.869) and extraneous CL (the last five items; Cronbach's α = 0.840). Sample intrinsic CL questions: 'The topics covered in the e-text were very complex'; 'I invested a very high mental effort in the complexity of the e-text content'. Sample extraneous CL questions: 'Manipulating e-texts was very distracting'; 'Reading e-texts from a screen was, in terms of learning, very ineffective'. The subscale scores were calculated by averaging the items of each subscale. The instrument was validated with 1377 undergraduate students (Novak et al., 2018a).

Student Motivation associated with a self-directed use of e-text materials was assessed using a simplified version of Keller's (1993, 2010) instructional material motivation survey. The instrument included four subscales measuring the four motivational dimensions of the Attention, Relevance, Confidence and Satisfaction (ARCS) model (Cronbach's α = 0.920). Each subscale included four Likert-type items with response choices ranging from 1 (not true) to 5 (very true)—a total of 16 items (Appendix B). The minimum possible score was 1 and the maximum possible score was 5. The subscale scores were calculated by averaging the four items of each subscale, and the total motivation score was calculated by averaging all 16 items. The instrument and its four subscales had a moderately high level of internal consistency (Cronbach's $\alpha_{\text{ATTENTION}}$ = 0.791; Cronbach's $\alpha_{\text{RELEVANCY}}$ = 0.614; Cronbach's $\alpha_{\text{CONFIDENCE}}$ = 0.748; and Cronbach's $\alpha_{\text{SATISFACTION}}$ = 0.793). It was validated with thousands of participants in various educational settings (eg, Huang et al., 2006; Novak et al., 2018b).

Data analysis

The ETFS psychometric properties were investigated using factor analytic techniques. In this cross-validation study, the data were randomly split into two separate halves. The first half of the data was used for EFA. In this exploratory phase, Principal Axis Factoring estimation with Direct Oblimin rotation was used to understand the underlying pattern of the scale in its factor structure (Brown, 2015; Thompson, 2004). The number of factors to be extracted was determined using the scree plot examination, Kaiser's rule (ie, the number of eigenvalue greater than 1) and Horn's parallel analysis. After extracting the factor structure of the ETFS, the internal consistency of the subdomains and whole scale were examined using McDonald's coefficient omega.

Once the factor structure of the ETFS was determined in EFA, CFA was conducted to validate the scale. Due to the ordinal nature of the data, the weighted least square mean and variance adjusted estimator (WLSMV; Muthén & Muthén, 2007) was used. Model fit was investigated using several indices (Kline, 2015): (1) chi-square (χ^2), (2) root-mean-square error of approximation (RMSEA), (3) comparative fit index (CFI), (4) Tucker–Lewis index (TLI) and (5) standardized root-mean square residual (SRMR). Non-significant results were warranted for the chi-square. Values less than 0.06 for RMSEA and less than 0.08 for SRMR (Hu & Bentler, 1999) were considered good fit. In addition, CFI and TLI values closer to 0.95 and higher were considered good fit (Bentler, 1990; Hu & Bentler, 1999).

Following this initial evaluation of the ETFS, we examined the ETFS measurement invariance (MI) in males and females. MI analyses reveal whether the construct has the same psychometric properties in different groups (Brown, 2015). Using the Kryiazos' (2018) *3-faced construct validation method*, we employed the entire sample to examine the ETFS MI. Configural, metric, scalar and strict invariance were tested in the MI analyses. In addition, factor loadings, intercepts and residuals were consecutively constrained to equality. Similar to CFA, the χ^2, RMSEA, SRMR, CFI and TLI values were checked. The examination between models (eg, configural vs. metric) was completed by checking the changes between the χ^2 (non-significant result is desired). In addition to the χ^2, the changes in the CFI (ΔCFI) across the models were investigated using the criteria of the ΔCFI less than 0.01 (Cheung & Rensvold, 2002).

Lastly, the relationships among students' e-text frustration measures, CL and motivation were examined using bivariate correlations. All analyses were conducted in R (R Core Team, 2021).

RESULTS

Data screening

A total of 896 students participated in this study. The data were screened by checking descriptive statistics and missing data. Table 1 presents descriptive statistics for all 11 items. Due to the non-normality and ordinal structure of the items, polychoric correlations were computed (Table 1). The data had some incomplete cases. Cases with more than 25% missing values were excluded from further analyses. Remaining missing data were imputed using multiple imputation using the *mice* package in R. Potential outliers were investigated using Mahalanobis distance. The final data set included 650 participants that were randomly split into two roughly equal halves with the first data set of 328 cases (ie, EFA sample) and the second one of 322 cases (ie, CFA sample).

Exploratory factor analysis

In the EFA data set ($n = 328$), the appropriateness and sufficiency of the data for a factor analysis were examined. The factorability of the data was assessed using Bartlett's test of sphericity (Bartlett, 1954). The test was significant ($\chi^2 = 2293.508$, $df = 55$, $p < 0.001$), indicating that there were relationships among the instrument's variables and the variables were influenced by some underlying latent factors. Additionally, the sampling adequacy was examined using the Kaiser–Meyer–Olkin (KMO) measure (Kaiser, 1958); the KMO measure had a value of 0.89, which was considered meritorious (Kaiser, 1974).

To determine the number of factors to be retained, the scree plot examination, Kaiser's rule (ie, the number of eigenvalue greater than 1) and Horn's parallel analysis were conducted. There were seven eigenvalues greater than 1 with the eighth largest eigenvalue being 0.996. Both the scree plot and Kaiser's rule indicated three factors. However, Horn's parallel analyses suggested a four-factor solution. To find the most intuitive factor solution, both three- and four-factor solutions were investigated using Principal Axis Factoring with Direct Oblimin rotation. The results from these two models revealed that the three-factor solution yielded more interpretable factors for the construct.

This three-factor solution accounted for approximately 65.7% of the total variance. The pattern matrix for the final model is shown in Table 2. The first factor had four items and was labelled as *e-text interaction*. The second factor consisted of four items pertaining to *technology*. The third factor was labelled *curriculum* and had four items.

To assess the internal consistency of the scale, McDonald's coefficient omega was calculated. Indicators associated with e-text frustration (F1, F2, F7, F8), technology frustration (F3, F4, F5, F6) and curriculum frustration (F9, F10, F11) yielded coefficient omega values of 0.872, 0.862 and 0.865 respectively. The coefficient omega for the overall frustration index was 0.944.

Confirmatory factor analysis

After retaining the three-factor structure for the ETFS using EFA, CFA was conducted using the second half of the data ($n = 322$). Since the scale included ordinal items, the WLSMV estimator was used. Using 11 items loading on the three factors, the CFA results showed a good fit for this model ($\chi^2 = 89.48$, $df = 41$, $p < 0.001$, $CFI = 0.948$, $TLI = 0.930$, $RMSEA =$

TABLE 2 Principal axis factoring (exploratory factor analysis) with Promax rotation ($N = 328$)

		Factor		
Item		1	2	3
F7	Reading from a screen	0.893		
F8	Lack of physical structure of the content like in print materials	0.822		
F1	Highlighting, bookmarking and personalizing e-texts	0.631		
F2	Navigating and searching e-text content	0.598		
F5	Limited access to laptop or tablet to view the e-text content		0.889	
F6	Limited usability on mobile devices		0.778	
F4	Limited or no Wi-Fi access		0.691	
F3	Technical issues and software glitches		0.435	
F11	Course instructor did not reference the e-texts			0.945
F9	E-text content is not aligned with course curriculum			0.603
F10	No syllabus for online assignments			0.598

Note: The first factor is labelled as 'e-text frustration', the second factor is labelled as 'technology frustration' and the third factor is labelled as 'curriculum frustration'.

TABLE 3 Confirmatory factor analysis (CFA) standardized factor loadings for the e-text frustration scale ($n = 322$)

Items	β	SE	*R*-square
e-Text frustration			
F2	0.781	0.036	0.610
F8	0.766	0.032	0.586
F7	0.740	0.036	0.547
F1	0.694	0.040	0.482
Technology frustration			
F3	0.752	0.040	0.566
F5	0.714	0.039	0.510
F4	0.696	0.043	0.485
F6	0.664	0.044	0.440
Curriculum frustration			
F9	0.777	0.042	0.603
F10	0.763	0.044	0.583
F11	0.733	0.046	0.537

Note: β = standardized factor loadings. SE = standard errors.

0.061 with 90% confidence interval at [0.044, 0.078], *SRMR* = 0.044). All standardized factor loadings were statistically significant ($p < 0.001$) ranging from 0.664 to 0.781 (Table 3). The correlations between the factors were moderate and ranged from 0.605 to 0.712. Several modification indices were suggested statistically, but no changes on the model were made to keep the model parsimonious.

Measurement invariance

Multigroup confirmatory factor analyses were conducted to test the equivalence of the ETFS across gender. The number of male and female participants was 164 and 423 respectively. First, the equality of the ETFS' factor structure was assessed using configural invariance across males and females. In this initial model, the three-factor model with 15 items in the ETFS was examined simultaneously for both male and female groups. The results showed a good model fit ($\chi^2 = 178.341$, *df* = 82, $p < 0.001$, *CFI* = 0.947, *TLI* = 0.928, *RMSEA* = 0.063 with 90% confidence interval at [0.051, 0.076], *SRMR* = 0.043), which indicates the equivalence of the factor structure of the ETFS for male and female groups. After this initial step, we assessed metric invariance, which tests the equivalence of the factor loadings for both groups. The model fit the data well ($\chi^2 = 171.518$, *df* = 90, $p < 0.001$, *CFI* = 0.955, *TLI* = 0.945, *RMSEA* = 0.056 with 90% confidence interval at [0.043, 0.068], *SRMR* = 0.047). The comparison of the metric and configural models indicated that the chi-square difference test was not statistically significant, $\Delta\chi^2 = 9.905$, $\Delta df = 8$, $p = 0.27$. Additionally, the changes in CFI between the models were less than 0.01. Together these results show that the model fit did not change considerably after constraining the factor loadings to be equal across groups. Since the metric invariance was established, the scalar invariance was tested by constraining both factor loadings and item intercepts to be equal for male and female participants. The model fit the data well ($\chi^2 = 182.886$, *df* = 98, $p < 0.001$, *CFI* = 0.953, *TLI* = 0.947, *RMSEA* = 0.054 with 90% confidence interval at [0.042, 0.067], *SRMR* = 0.048). The comparison of the scalar and metric models indicated that the chi-square difference test

was not statistically significant, $\Delta\chi^2 = 11.241$, $\Delta df = 8$, $p = 0.19$. Additionally, the changes in CFI between the models were less than 0.01. These results show that all item intercepts were invariant across gender. Finally, strict factorial invariance was examined. In addition to factor loadings and item intercepts, item residuals hold to be equal across groups. The results showed a good fit ($\chi^2 = 194.462$, $df = 109$, $p < 0.001$, $CFI = 0.953$, $TLI = 0.952$, $RMSEA = 0.052$ with 90% confidence interval at [0.04, 0.063], $SRMR = 0.05$). The changes in χ^2 between strict and scalar invariance models were not statistically significant, $\Delta\chi^2 = 14.25$, $\Delta df = 11$, $p = 0.22$. Altogether, these results suggest that the ETFS indicates strict invariance across males and females (Table 4).

Bivariate correlations

Subsequent analyses examined construct validity by correlating e-text frustration with measures of CL and motivation. Descriptive statistics for the three frustration indices, students' motivation, and intrinsic and extraneous CL, are included in Table 5.

The correlations between e-text frustration, e-text CL and motivation were examined using a Pearson's correlation coefficient (Table 6). Bivariate analyses revealed significant, negative correlations between students' frustration and their e-text motivation. Lower levels of frustration correlated with higher levels of motivation and vice versa. Moreover, analyses highlight significant, positive correlations between CL and these frustration measures. Higher levels of frustration are associated with significantly higher CL and vice versa, except that the correlation between intrinsic CL and frustration with curriculum was not statistically significant. Significant relationships are in the expected directions, with higher CL being associated with higher frustration, and higher levels of motivation being associated with lower levels of frustration.

DISCUSSION

E-texts have become an integral part of todays' education and the rapid growth of e-learning technologies is expected to contribute to the further expansion of digital learning materials (Dennis, 2011). Nevertheless, little is known about student frustration with e-texts and the barriers that these frustrations bring to learning. User satisfaction with technology is viewed

TABLE 4 The ETFS measurement invariance across gender

Model	χ^2 (*df*)	RMSEA [90% CI]	SRMR	CFI	TLI	Model comparison	$\Delta\chi^2$ (Δdf)	ΔCFI
1. Configural	178.341 (82)	0.063 [0.051, 0.076]	0.043	0.947	0.928	–	–	–
2. Metric	171.518 (90)	0.056 [0.043, 0.068]	0.047	0.955	0.945	1 versus 2	9.905 (8)	0.008
3. Scalar	182.886 (98)	0.054 [0.042, 0.067]	0.048	0.953	0.947	2 versus 3	11.241 (8)	0.002
4. Strict	194.462 (109)	0.052 [0.04, 0.063]	0.05	0.953	0.952	3 versus 4	14.25 (11)	0

TABLE 5 Descriptive statistics of variables measured in study (CFA sample)

	Mean	SD	Min	Max	*N*
e-Text frustration					
Frustration with e-text interactions	3.58	1.69	1	7	322
Frustration with technology	3.30	1.60	1	7	322
Frustration with curriculum	2.61	1.58	1	7	322
Cognitive load indices					
Intrinsic cognitive load index	5.20	1.99	0	10	317
Extraneous cognitive load index	4.02	2.39	0	10	307
e-Text motivation					
Attention	2.85	0.96	1	5	317
Relevance	3.23	0.85	1	5	316
Confidence	3.31	0.92	1	5	313
Satisfaction	3.14	0.92	1	5	316

Note: Possible score range for motivation and its four subscale scores: 1–5.

Possible score range for intrinsic and extraneous cognitive load: 0–10.

TABLE 6 Relationships between frustration indices, measures of motivation, cognitive load, comfort level with e-texts and biology, and academic preparation

	Frustration w/e-text interactions	Frustration w/ technology	Frustration w/curriculum
Cognitive load			
Intrinsic cognitive load	0.12*	0.15**	0.05
Extraneous cognitive load	0.61**	0.32**	0.29**
Motivation index			
Attention	−0.48**	−0.24**	−0.26**
Relevance	−0.45**	−0.26**	−0.40**
Confidence	−0.52**	−0.32**	−0.44**
Satisfaction	−0.62**	−0.30**	−0.40**

*$p < 0.05$; **$p < 0.01$.

as an affective measure of a student's success using technology (Collins et al., 1999). As such, a successful completion of a task or a goal, such as the use of e-text, is directly related to student satisfaction with e-text learning. Frustration occurs when there is a barrier or an interruption of the student's ability to attain their goal (Bessière et al., 2006). Thus, the identification of those factors that block students' ability to attain their goals, in this case successfully using e-texts to learn, is important to creating positive e-learning environments and experiences.

Validation of the ETFS

This study empirically investigated undergraduate biology students' frustration with e-texts and validated the ETFS that can help better understand some of the major sources of e-text frustration experienced by students. Using EFA, the frustration indicators loaded on three

factors: (1) frustration with e-text interactions (eg, navigating, bookmarking, highlighting, personalizing e-text), (2) frustration with technology to access the e-texts (eg, lack of Internet connection, limited accessibility on mobile devices) and (3) frustration with e-text curricular issues (eg, lack of instructional alignment between e-text and course syllabus, no syllabus for e-text online assignments, limited use of e-text by instructors). This structure was confirmed by CFA. The ETFS showed evidence of high level of internal consistency for research purposes (coefficient omega = 0.944).

Furthermore, the MI analyses of the EFTS provided additional evidence for the scale validity indicating that the ETFS measures the same construct in the same way in males and females. This initial development of the scale suggests that the ETFS is a useful instrument with high reliability and validity evidence that can be used by researchers and practitioners.

On average, the highest source of students' e-text frustration related to e-text interactions (3.58 on a scale 1–7), followed by frustration with technology to access the e-text (3.30 on a scale 1–7) and e-text curricular issues (2.61 on a scale 1–7). It is important to mention that limited or no Wi-Fi access, limited usability on mobile devices, reading from a screen and a lack of physical structure of the content, such as in print materials, were the strongest sources of students' e-text frustration. These findings suggest that while e-texts offer benefits to the student, such as the ability to highlight, search content and view media, these advantages can also serve as sources of frustration. In addition, e-texts rely upon connectivity to the Internet and student ability to access them on various devices, so when these do not function properly, students may become frustrated. One of the interesting findings of this study is students' frustration with the lack of alignment between the course e-text and curriculum. This finding is consistent with literature arguing that an instructor's use of e-texts directly influences the students' e-text preferences (Dennis, 2011; Weisberg, 2011) as the instructor's use sets clear expectations for student success (Thomas, 2013). For instance, if the instructor consistently references the e-text in the classroom or course syllabus, it most likely prompts students to review the referenced e-text materials. Conversely, if the e-text online activities are not part of the course requirements, students receive mixed messages regarding the importance of using the e-text, which contributes to the lack of satisfaction and frustration with the learning process. In the educational setting, the instructor has little control over the actual functioning of the machine or the connectivity of the Internet. However, there is great control over how the e-text is used in the classroom. As such, referencing e-text in the course syllabus and classroom can help manage students' e-text learning expectations and reduce frustration with e-text learning.

Relationships among e-text frustration, CL and motivation

Consistent with the RH 3.1 study hypothesis, students' extraneous CL significantly and positively correlated with the three frustration measures representing factors that are extraneous to the learning process. These findings are consistent with the literature asserting that both frustration and extraneous CL involve processes that require a redirection of an individual's cognitive resources to activities that are extraneous to learning, thus inhibiting the learning process (D'Mello, 2017; Markus, 1990; Sweller, 2010). Specifically, our findings revealed a significant extraneous CL correlation of 0.61 with e-text frustration (eg, navigating the e-text), 0.32 with e-text technology (eg, looking for the Internet connection or device to read the e-text) and 0.29 with e-text curriculum (eg, figuring out how the e-text materials relate to the course). These factors are extraneous to the learning process but have a great effect on learning with e-texts.

Students' intrinsic CL significantly and positively correlated with frustration with e-text interactions and frustration with technology, thus implying a positive relationship among the cognitive demands associated with the e-text learning process and e-text frustration. Although the intrinsic CL correlation coefficients were smaller (0.12 with e-text frustration and 0.15 with e-text technology) than the extraneous CL ones, they are still an important part of understanding student frustration with e-text. Intrinsic CL is imposed by a learner's prior knowledge and learning task difficulty (Sweller, 2010; Van Merriënboer & Sweller, 2005). Several E-Text Frustration items, for example reading off a screen and lack of physical structure of the content like in print materials, describe activities that are not extraneous to the e-text learning process, and therefore relate to intrinsic CL. These findings partially support the RH 3.2 study hypothesis, as there was non-significant correlation between intrinsic CL and frustration with curriculum.

The results from the bivariate correlations revealed that the four motivation subscales, for example attention, relevance, confidence and satisfaction, negatively correlated with the three e-text frustration measures. The correlations between the frustration with technology and frustration with curriculum EFTS factors and motivation subscales ranged between 0.12 and 0.44. Higher correlations (ranging between 0.48 and 0.62) were observed between the frustration with e-text interactions factor and motivation, suggesting a medium to strong association of the frustration with e-text interactions factor with motivation. Nevertheless, the ETFS represents a unique construct, as frustration is the result of a block in the path towards successful learning while motivation refers to learner desire to learn. Specifically, the attention category of the ARCS model captures learners' interest and curiosity to learn (Keller, 1999) and therefore higher levels of e-text frustration negatively correlate with learner's attention towards the e-text. Many students from Study I commented on several e-text features that stimulated their interest, like a variety of different learning tasks and activities, a novel learning environment and high-quality e-text interface and visuals.

The relevance category highlights the importance of providing students with learning materials that are relevant to their personal and professional goals. Since frustration is defined as an 'emotional or pre-emotional response to unexpected obstacles impeding goal achievement' (Bessière et al., 2006, p. 942), students become frustrated when e-text materials do not appear relevant to their goals. For example, students from Study I mentioned that they benefited from having LearnSmart adaptive activities and quizzes, which were part of their course homework, linked directly to relevant text sections.

Even if the students find the e-texts interesting and relevant to their personal goals, their confidence (the confidence category of the ARCS model) with successful e-text learning may interfere with their motivation to learn. Our findings suggest a negative relationship among students' e-text frustration and their beliefs that they can successfully learn with e-texts, because struggling with e-text use lowers students' confidence or expectancy for success with e-texts.

Satisfaction is the last dimension of the ARCS model. User satisfaction with technology directly influences individual's continued desire to use the technology and attitudes towards it (Deng et al., 2010; Kang & Lee, 2010; Sepehr & Head, 2018). As such, high student satisfaction with e-text learning is associated with low e-text frustration. For instance, among the positive e-text features mentioned by students from Study I was portability. Students were able to spend more time studying with e-texts outside the class, because they could open the e-text anytime they wanted and did not need to have a hard copy book with them.

In summary, the findings from the bivariate correlations between students' perceived frustration and motivation and CL variables indicate that the ETFS theoretically relates to these two constructs, thus providing support for the ETFS construct validity.

LIMITATIONS

This study has several limitations. First, the sample was limited to undergraduate biology students only. As such, caution is needed to broadly generalize the findings to other majors and/or educational settings. Second, the ETFS development was informed by students' responses to a survey that asked them to answer two open-ended questions related to their positive and negative e-text experiences, which could have limited the range of possible sources of frustration reported by the students. For example, students' learning disabilities could have impacted their e-text frustration. In addition, this study examined the ETFS MI using an entire sample based on the Kyriazos' (2018) model. However, the distribution of male and female participants was uneven. Since a scale development is an iterative process (Kyriazos & Stalikas, 2018), future studies should investigate the EFTS MI by gender using a more balanced sample.

CONCLUSIONS

Frustration with technology has not been rigorously conceptualized as a factor in the field of human–computer interactions. Research on frustration with educational technology is even more limited. This study was among the first ones to examine frustration with e-texts. It examined the sources and levels of undergraduate students' e-text frustration and developed the ETFS that has promising validity and reliability. Modern e-textbooks, like the ones used in this study, are not limited to an electronic presentation of a written text but embed additional e-learning technologies such as simulations, self-assessments and an adaptive learning environment, which can blur the distinction between modern e-textbooks and other e-learning technologies. Nevertheless, the ETFS focused on e-texts only and not on e-learning technologies in general, as the e-texts used by study participants were a major academic source of readings in their courses, and most of students' e-textbook interactions involved readings. As such, caution should be exercised when using the ETFS for evaluating student frustration with other e-learning technologies. For example, researchers interested in investigating general frustration with technologies that rely on Internet connection can use the Technology Frustration subscale. In addition, the Curriculum Frustration subscale can potentially be used for assessing student frustration with print textbooks in an academic course by adapting the language of the Curriculum Frustration subscale for print texts and assignments. Overall, this research can help investigators begin to understand the sources of learners' frustration with technology in educational settings and provide recommendations for reducing frustration with e-texts. In addition, it can raise awareness among educators and software developers about the factors that contribute to frustration with educational technology, which can increase academic achievement and technology adoption rates.

Identifying sources of frustration with e-texts, such as issues with the e-text itself, technological issues and curricular use of e-texts, informs practitioners and publishers to more effectively use these learning tools. For example, it is important for publishers to poll students and listen to student preferences and what could be improved in the e-text. Assessments that measure student experiences with these tools should be a normal part of the e-text world. For instructors, this study can inform areas of frustration in the delivery of technology and the use of e-texts in the curriculum. For example, using e-texts in a rural community with limited Internet access is a recipe for frustration. Understanding the target student audience and the availability of resources can mitigate frustration with technology. For instance, tutoring sessions for students naive to technology may be considered. In addition, more attention should be given to better integrate e-texts into the curriculum so that it is not an 'add on' but an important part of the curriculum, as e-text curriculum issues can serve as a source of frustration.

FUTURE RESEARCH RECOMMENDATIONS

Future research should attempt to further explore the sources of frustration with e-texts and other learning technologies with different student populations from different academic disciplines. For instance, using a variety of data collection methods and sources, such as interviews and surveys with targeted questions about frustration with learning technologies, may help identify additional sources of frustration, which can be then empirically tested by replicating the present study. Moreover, it would be important to examine whether student frustration as well as the sources of the frustration vary across different digital learning environments, tools and learning activities. For example, reading an e-text can involve different sources of frustration than using a simulation for practicing the taught concepts. Additionally, it would be important to investigate individual differences in student frustration. For instance, how various demographic variables (eg, age, learning disabilities), personality traits (eg, neuroticism, Rose et al., 2002) and prior experiences and knowledge affect a student's levels of frustration? If frustration is viewed as a barrier or an interruption of the student's ability to attain their goal, how does frustration with technology affect information processing, motivation and learning? Finally, future research should investigate how to reduce students' frustration with educational technologies to provide them with better learning experiences.

CONFLICT OF INTEREST
The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT
The data sets used and/or analysed during the current study are available from the corresponding author on reasonable request.

ETHICS STATEMENT
The research was approved by an Institutional Review Board.

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APPENDIX A

E-TEXT COGNITIVE LOAD QUESTIONNAIRE (NOVAK ET AL., 2018A)

Instructions: There are nine statements in this questionnaire. Please think about each statement in relation to the e-text you used in this course. Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear. Think about each statement by itself and indicate how true it is on a scale from 0 (*Not at all*) to 10 (*Completely the case*). Do not be influenced by your answers to other statements.

1. The topics covered in the e-text were very complex.
2. The e-text covered content that I perceived as very complex.
3. The e-text included very complex case studies and concepts.
4. I invested a very high mental effort in the complexity of the e-text content.
5. Manipulating e-texts (eg, highlighting, bookmarking, navigating, searching information) was very distracting.
6. Manipulating e-texts (eg, highlighting, bookmarking, navigating, searching information) was, in terms of learning, very ineffective.
7. I invested a very high mental effort in ineffective e-text manipulation.
8. Reading e-texts off a screen was, in terms of learning, very ineffective.
9. I invested a very high mental effort in reading e-texts off a screen.

APPENDIX B

INSTRUCTIONAL MATERIAL MOTIVATION SURVEY (KELLER, 1993, 2010)

Instructions: There are 16 statements in this questionnaire. Please think about each statement in relation to the e-text you used in this course and indicate how true it is. Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear.

		Not true	Slightly true	Moderately true	Mostly true	Very true
1	The way that the content of the e-text was introduced got my attention	1	2	3	4	5
2	The e-text made me curious	1	2	3	4	5
3	The e-text was boring	1	2	3	4	5
4	Finishing the e-text readings successfully was important to me	1	2	3	4	5
5	I can see how the content of the e-text is related to things I already know about	1	2	3	4	5
6	The knowledge in the e-text is NOT useful to me	1	2	3	4	5
7	The way that the information was organized made me feel that I could be successful in working with the e-text	1	2	3	4	5
8	I could understand most of the content of the e-text	1	2	3	4	5

		Not true	Slightly true	Moderately true	Mostly true	Very true
9	After I worked with the e-text for a while, I felt confident about what I was doing	1	2	3	4	5
10	I was happy about finishing the e-text successfully	1	2	3	4	5
11	I did NOT think the e-text was well designed	1	2	3	4	5
12	I liked working with the e-text	1	2	3	4	5
13	This material was more difficult to understand than I would like for it to be	1	2	3	4	5
14	The e-text had things that stimulated my curiosity	1	2	3	4	5
15	I could relate the e-text content to things I have seen, done, or thought about in my own life	1	2	3	4	5
16	It was a pleasure to work with such a well-designed e-text	1	2	3	4	5