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Structure Building Predicts Grades in College Psychology and Biology

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Summary: Knowing what skills underlie college success can allow students, teachers, and universities to identify and to help at-risk students. One skill that may underlie success across a variety of subject areas is structure building, the ability to create mental representations of narratives (Gernsbacher, Varner, & Faust, 1990). We tested if individual differences in structure-building ability predicted success in two college classes: introductory to psychology and introductory biology. In both cases, structure building predicted success. This effect was robust, with structure building explaining variance in course grades even after accounting for high school GPA and SAT scores (in the psychology course) or a measure of domain knowledge (in the biology course). The results support the claim that structure building is an important individual difference, one that is associated with learning in different domains. Copyright © 2016 John Wiley & Sons, Ltd.

Success in college requires learning, retaining, and applying large amounts of information. Far from straight memorization, students must think critically and often need to go beyond given information, such as when they design experiments or develop arguments. Success likely depends upon many skills, including reading comprehension, writing proficiency, reasoning ability, and the ability to work with numbers, among other things. Here we focus on one specific skill that may support academic success: structure-building, the ability to build a "cohesive, mental representation or 'structure'" of any event, whether read or encountered via some other modality (Gernsbacher, Varner, & Faust, 1990, p. 431).

To understand the concept of structure-building and how it supports learning, consider the following text from a biological psychology textbook:

> *Working memory enables an individual to respond to a stimulus that was heard or seen a short while earlier*, *as tested in various forms of the* ***delayed response task***. *For example*, *an animal might see a light shine above one of several doors*. *When the light goes off*, *the animal waits through a specified delay*, *and then has to go to the door where it saw the light* (Kalat, 1998).

The less-skilled comprehender might represent the concepts of working memory and the delayed response task separately, failing to integrate the two concepts in a unified structure. In contrast, the skilled comprehender will map the new information about the delayed learning task onto their existing representation of working memory, creating a unified structure. These representations have implications for understanding the text; frequent shifts from existing to new structures reduce comprehension and may therefore reduce academic success across a variety of subject areas.

An assumption of the structure building framework is that narratives have a structure and that comprehension involves building a coherent mental model that captures this intended structure. This framework argues the process of building this model is similar whether the narrative is presented visually, auditorily, or pictorially. Evidence for this general comprehension ability stems from Gernsbacher's Multimedia Comprehension Battery (MMCB; Gernsbacher & Varner, 1988). In its entirety, this battery consists of multiple stories, each presented in one of three modalities: written, auditory, or pictorially, with comprehension questions following each story. Comprehension scores from the different modalities are highly correlated (*r*s range from .72 to .92), and a principle-component analysis showed that one factor, a general comprehension ability, underlies comprehension in all modalities (Gernsbacher et al., 1990). Gernsbacher and her colleagues argue that this general ability is related to how well one can suppress information irrelevant to one's emerging representational structure. A deficit in suppression causes low comprehenders to frequently shift to new structures because the irrelevant information does not map onto the existing structure. Frequent shifting causes a disjointed narrative representation, thereby reducing comprehension.

This framework is normally discussed in terms of comprehending a single narrative from one source, but can be applied to situations where one must integrate material from multiple sources. Consider the student learning about working memory and the delayed response task; the student might hear a lecture that relies on the operation-span task as the measure of working memory, and then later read a textbook passage where working memory is measured via the delayed response task. The learner does not necessarily want to create separate representations for these two sources; rather, the goal should be to extract an integrated representation (structure) across sources. In this sense, students likely face a more challenging task than does the typical laboratory subject; in classes, students often build mental models over time and across sources, as opposed to laboratory experiments that typically require building a representation of a single text. Frequent shifting may be more likely in classroom situations, given

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that learning is often spread over time and may involve integration across lectures, textbooks, slides, discussions, problem sets, graphs, and videos. The resulting disjointed models would then hinder students' abilities to make inferences and connect information presented through multiple sources. In other words, the classroom may be a learning environment for which structure-building skills are of great importance. For these reasons, we believe it is crucial to investigate the relationship between structure-building and classroom performance.

In contrast to our approach, the literature is relatively silent as to which specific skills predict college success (with the exceptions of working memory and reading comprehension, as discussed at the end of this paper). Instead, the focus has been on measures of past successes. The best predictors of college success include high school GPA (Cohn, Cohn, Balch, & Bradley, 2004), high school class rank (e.g. Baron & Norman, 1992), and scores on standardized tests such as the ACT and the SAT (Hannon, 2014). Such measures are sufficient if the goal is prediction, but they provide little insight into the specific skills or knowledge to target for improvement. More targeted predictors focus on what knowledge and skills a student needs to succeed in a particular subject matter, such as the Force Concept Inventory (FCI). This inventory measures student understanding of force and related kinematics, and correlates with performance in introductory physics classes at both the high school and university levels (Hestenes, Wells, & Swackhamer, 1992; Savinainen & Scott, 2002; see also Cahill et al., 2016, extending these findings to second semester introductory university courses, using the Brief Electricity and Magnetism Assessment [BEMA] as a predictor of course performance). However, while such measures can be extremely useful within specific classes, they are limited in their ability to generalize across subject areas.

There is initial evidence supporting the possibility that structure-building is associated with success in college, and that its predictiveness will not be limited to a particular subject matter. Several laboratory studies have examined the relation between structure building (as measured by MMCB scores) and learning of classroom-like materials. Structure-building ability is significantly related to learning (test performance) after reading a psychology textbook selection (Callender & McDaniel, 2007) or listening to a lecture about how a mechanical device works (Bui & McDaniel, 2015). It is associated with the accuracy of confidence judgments, with better comprehenders more accurately assessing their relative test performance (Maki, Jonas, & Kallod, 1994), and the efficiency with which study time is regulated (Martin, Nguyen, & McDaniel, 2015). In addition, one previous study examined whether structure-building predicts academic success in an actual classroom (Maki & Maki, 2002). This work was focused on whether course format (in-person vs. web-based lectures) affected learning; the MMCB was used to examine whether the conclusions depended upon the comprehension skills of the learner. MMCB significantly predicted exam performances for students in both the web course and the traditional class, and significantly predicted performance in the web course on a post-course measure consisting of practice items from the Psychology GRE exam. Thus, the available evidence, although minimal, is encouraging regarding our hypothesis that structure-building ability might be related to learning in authentic academic contexts.

To extend the existing work, we examined a range of predictors of success in addition to structure building ability in two very different college courses: Psychology and Biology. At two different institutions, instructors[1] administered the MMCB to their classes, and we looked at the relationship between MMCB and course grades. In both courses, additional measures were collected that allowed us to evaluate the relationship between MMCB and grades after controlling for more standard predictors. In the Psychology course, a subset of students provided their high school GPAs and standardized test scores, two 'gold standard' measures of past performance. In the Biology course, a subset of students completed two measures of biology/science knowledge and skills, the Biology Concept Inventory (BCI) and the Lawson's Classroom Test for Scientific Reasoning (LCTSR); both measures focused on science. We asked three questions: (i) What is the relationship between structure-building (as measured by MMCB) and the typical predictors of academic success? To the extent that these measures are correlated, it would suggest that structure-building ability may be one of the skills underlying performance on those measures. (ii) Does structure-building predict success in college, and is it similarly predictive in a Social Science (Psychology) and Natural Science Course (Biology)? (iii) Does structure building predict success over and above the traditional predictors, including measures of past performance (in the Psychology course) and knowledge/skills specific to the class topic (in the Biology course)?

METHODS

Participants

Psychology

Nine hundred fifty-four undergraduate James Madison University students (594 females) enrolled in Introduction to Psychology participated in the study. Most students were between 18 and 21 years old ($n = 935$), were in their first ($n = 614$) or second ($n = 243$) year of college, and were native English speakers ($n = 925$). SAT scores and high school GPAs for 148 1st semester students were obtained from university records.

Biology

One hundred four undergraduate Brigham Young University students enrolled in an introduction to biology course for non-majors participated in the study. Students were in their first ($n = 40$), second ($n = 39$), third ($n = 14$), or fourth ($n = 10$) year in college. No other demographics were collected. In addition to the MMCB, 83 students completed two additional individual difference measures: the LCTSR and the BCI.[2]

[1] The instructors were the second (psychology) and third (biology) authors.
[2] Fifty-six biology students released their combined SAT and/or ACT scores. Because of this relatively small sample size for measuring individual differences and the lack of subscores, standardized test scores were not analyzed in this course.

Materials

MMCB

Following previous studies (Bui & McDaniel, 2015; Callender & McDaniel, 2007; Callender & McDaniel, 2009; Martin et al., 2015), we used only the written version of the MMCB, which is sufficient for measuring a general structure building ability. In both courses, four passages from the Multi-Media Comprehension Battery (MMCB; Gernsbacher & Varner, 1988) were used to measure individual differences in structure building. The four passages ranged in length from 538 to 957 words, and each had 12 corresponding multiple-choice questions about key details from the passage, for a total of 48 questions. The questions corresponding to each passage were answered immediately following the reading of that passage, without access to the passage. Scores could range from 0 to 48.

The biology sample had good reliability (Cronbach's alpha = .85), but reliability could not be calculated in the psychology sample because scores on individual questions were not available. However, prior studies have consistently shown the MMCB to be reliable (Callender & McDaniel, 2009; Gernsbacher et al., 1990).

SAT

The SAT is a standardized aptitude test used for college admissions. The Psychology instructor collected scores on the math and verbal subsections, each of which has a maximum score of 800 for a combined total maximum of 1600 for those two sections.

High school GPA

High school GPA was collected through self-report in the Psychology course. GPAs that were reported on a 100-point scale were converted to a 4-point scale.

Scientific reasoning and biological content knowledge measures

Two additional measures were collected in the Biology course. First, science reasoning ability was measured using the revised version of LCTSR (Lawson, 1978; Lawson et al., 2000), which is a content-independent test of basic scientific reasoning ability. The LCTSR consists of 12 pairs of questions, for a total of 24 multiple-choice questions. The first question in a pair requires the student to answer a science-reasoning problem and the second asks the student to explain how the answer was derived. Scores can range from 0 to 24. The LCTSR had good reliability in our sample (Cronbach's alpha = .83).

Second, knowledge of biology was assessed with the BCI, which consists of 30 multiple-choice questions (Klymkowsky, Underwood, & Garvin-Doxas, 2010). The BCI was designed to identify common student misconceptions with questions grouped by topics such as molecular properties and functions, genetic behaviors, and evolutionary processes. Scores can range from 0 to 30. Validity and reliability of this measure at the individual question level have been previously reported (Klymkowsky, Underwood, & Garvin-Doxas, 2010). However, to our knowledge overall internal consistency has not been previously assessed. In our own sample, internal consistency was low (Cronbach's alpha = .38), possibly because of the multidimensional nature of the inventory.

Design and procedure

Psychology

Students were enrolled in one of two Introductory Psychology classes with both classes taught by the same instructor (the 2nd author). On the first day of class, students completed the MMCB. Final course grades were based on performance on 12 quizzes and 4 exams, which were spaced out across the semester. Quizzes were given at the beginning of class and covered the previous reading assignment. Exams were not cumulative and covered material from both lecture and reading. Questions on both the quizzes and exams were multiple-choice and scored by scantron.

Biology

Students were enrolled in one of two Introductory Biology for non-majors classes; both classes were taught by the same instructor (the third author). Students completed the LCTSR and the BCI within the first two weeks of the semester and the MMCB at the end of the semester in conjunction with the final exam. Final course grades were based on performance on three unit exams, one final cumulative exam, 26 quizzes, homework assignments, and class participation. Quizzes consisted of four multiple-choice questions answered using an interactive response device (clicker). Homework assignments involved open-book quizzes on the assigned reading. Unit exams were open-book (i.e., students could refer to their textbook and notes) and consisted of 75 multiple-choice questions. The final exam was closed-book and consisted of 80 multiple-choice questions.

RESULTS

Table 1 presents average final course grade and MMCB score for both classes. MMCB scores were similar across the two courses ($t < 1$), were neither at ceiling nor floor, and had sufficient variability to examine individual differences. Table 1 also shows average SAT score and high school GPA for those students who provided them, and scores on the two science knowledge/ability measures from the subset who took them.

Question 1: **Is Structure-Building Related to Past Academic Success and/or Domain-Specific Measures**? Our hypothesis implies that MMCB scores should be correlated with measures of past academic success in the same way they are hypothesized to be related to current academic success. To evaluate this idea, we examined the correlations in the Psychology sample between the MMCB and the two measures of past success: SAT scores and high school GPA. As shown in Table 2, higher MMCB scores were associated with better high school grades ($r = .33$ $p < .001$) and with higher SAT Verbal scores ($r = .16$, $p = .047$); as might be expected, a similar relationship between MMCB and SAT Math did not reach significance. In contrast, MMCB scores were not correlated with either science measure (LCTSR, BCI) in the biology class.

Table 1. Mean scores and standard deviations (in parentheses) on the multi-media comprehension battery (MMCB), SAT—Verbal, SAT—Math, High School GPA, Lawson's Classroom Test for Scientific Reasoning (LCTSR), and the Biology Concept Inventory (BCI)

Course	Final grade	MMCB	SAT—Verbal	SAT—Math	HS GPA	LCTSR	BCI
Psychology	79.3 (8.9)	35.5 (5.4)	570.6 (66.6)	563.7 (73.9)	3.80 (.34)	—	—
Biology	87.7 (8.1)	35.5 (6.8)	—	—	—	17.5 (4.4)	10.6 (3.2)

Dashes indicate data were not collected or were not analyzed (because of low N for that measure). Possible scores for the following measures are as indicated: MMCB (0–48), LSCTSR (0–24), and BCI (0–30).

Table 2. Correlations between predictor variables in each course

	Course				
	Psychology ($n = 148$)			Biology ($n = 83$)	
Measure	MMCB	SAT—Verbal	SAT—Math	MMCB	LCTSR
SAT—Verbal	.16*				
SAT—Math	.08	.21*			
HS GPA	.33***	.19*	.12		
LCTSR				.15	
BCI				.06	.27*

MMCB = multi-media comprehension battery. LSCTSR = Lawson's Classroom Test for Scientific Reasoning. BCI = Biology Concept Inventory.
*$p < .05$.
***$p < .001$.

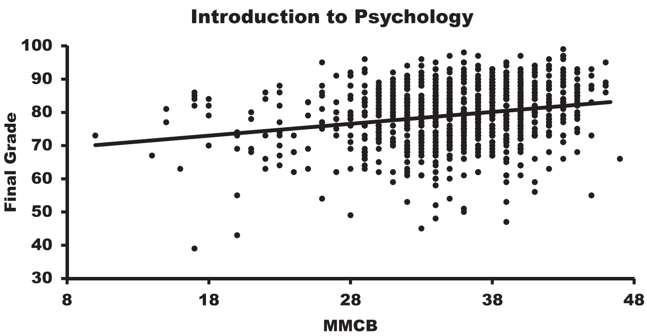

Figure 1. Final grades in the Introduction to Psychology course as a function of scores on the MMCB. The regression line is derived from the model with MMCB as the only predictor

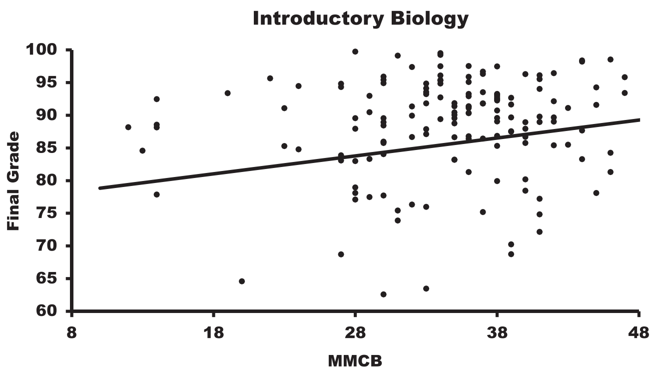

Figure 2. Final grades in the Introductory Biology for non-majors course as a function of MMCB scores. The regression line is derived from the model with MMCB as the only predictor

Question 2: **Can Structure-Building Predict Grades in College**? Figures 1 and 2 show that students with greater structure building ability performed better in both the Introduction to Psychology and the Introductory Biology courses. To confirm these effects, separate regression analyses with MMCB as the only predictor were computed for each course to determine if structure-building scores predicted final course grades. The results mirror the figures; structure building ability significantly predicted final grades in both courses (Psychology: $\beta = .22$, $p < .001$; Biology: $\beta = .29$, $p = .002$).[3] That is, one's ability to form a mental model of a narrative is related to one's outcomes in college classes.

Question 3: **Does Structure-Building Explain Additional Variance after Accounting for Traditional Predictors**? First, we examined whether MMCB scores predicted college performance over and above the gold standard of past performance in high school. We answered this question with the psychology sample, which included both SAT scores and High School GPA for 148 first semester students. These variables (SAT Verbal, SAT Math, and high school GPA) were entered into the first step of the regression, with MMCB scores added in the second step. Table 3 shows the expected relation between past performance (as measured by SAT and high school GPA) and performance in the present course: past performance was highly predictive of psychology grades. However, and more importantly for present purposes, adding the MMCB in Step 2 increased the model's predictive value ($\Delta R^2 = .04$, $p = .002$). Differences in structure building significantly predicted final grades in psychology ($\beta = .21$, $p = .002$), even after accounting for high school GPA and SAT scores.

Did MMCB scores predict performance in college Biology over and above the measures of scientific reasoning (LCSTR) and knowledge (BCI)? As with the prior analysis, the science variables were entered into the first step of the regression model, and MMCB scores were added in the second step. As Table 4 shows, science-reasoning skills, but not prior biology knowledge, predicted final course grades. More importantly, adding MMCB scores to the model increased its predictive value ($\Delta R^2 = .04$, $p = .048$). After accounting for science-reasoning skills and prior biology knowledge, structure building uniquely predicted final grades ($\beta = .20$, $p = .048$).

DISCUSSION

Student ability to construct coherent mental models (as measured by the MMCB) predicted grades in both college-level introductory psychology and introductory biology courses. This work moves the field beyond relying on past performance to predict future performance, and instead identifies a specific

[3] Psychology: *adjusted* $R^2 = .05$, Biology: *adjusted* $R^2 = .08$

Table 3. Regression results predicting final course grade in the psychology course using past performance (step 1) and MMCB (step 2)

	Psychology ($n = 148$)			
	F	ΔR^2	β	Part r
Step 1	32.20***	.40***		
SAT—Verbal			.39***	.37***
SAT—Math			.16*	.15*
HS GPA			.37***	.36***
Step 2	27.97***	.04**		
SAT—Verbal			.37***	.35***
SAT—Math			.15*	.15*
HS GPA			.31***	.28***
MMCB			.21**	.19**

MMCB = multi-media comprehension battery. Part r is equivalent to semipartial r and indicates the unique contribution of each independent variable.
*$p < .05$.
**$p < .01$.
***$p < .001$.

Table 4. Hierarchical regression results predicting final course grades in the biology course

	Biology ($n = 83$)			
Predictor variables	F	ΔR^2	β	Part r
Step 1	8.83***	.18***		
LCTSR			.36**	.35**
BCI			.15	.14
Step 2	7.45***	.04*		
LCTSR			.33**	.32**
BCI			.14	.14
MMCB			.20*	.20*

LCTSR = Lawson's Classroom Test for Scientific Reasoning. BCI = Biology Concept Inventory. MMCB = multi-media comprehension battery. Part r is equivalent to semipartial r and indicates the unique contribution of each independent variable.
*$p < .05$.
**$p < .01$.
***$p < .001$.

skill associated with academic success. Furthermore, this skill predicted performance in two disparate subjects, Psychology and Biology, suggesting structure building is a general comprehension skill that underlies academic success across domains. These findings extend Gernsbacher's structure building model (Gernsbacher, 1997) from explaining only narrative comprehension to also explaining important aspects of learning complex academic (non-narrative) information. Thus, these findings reinforce the preliminary evidence that structure building is a core skill in comprehension, regardless of the nature of the events or materials that the learner is trying to understand.

Structure building is clearly an important skill that is associated with learning. However, because of the correlational nature of this study, it is not clear if this skill directly impacts learning or if training in structure-building would result in higher grades. For example, it is possible that a third unmeasured variable is driving both scores. However, we do think it is noteworthy that prior laboratory studies have shown that certain interventions can help less-able structure-builders compensate for their poor structure building skills. Less-able structure-builders show improved learning and memory for texts when required to answer embedded questions while reading a textbook (Callender & McDaniel, 2007) or when forced to consider the relationships between parts of the text (e.g., by unscrambling it; McDaniel, Hines, & Guynn, 2002). A more tractable technique for the classroom that has shown success in the laboratory is to provide aids during lecture that help scaffold construction of a mental model of the system or process that the lecture is targeting by providing illustrative diagrams to the learner (Bui & McDaniel, 2015). However, no studies have yet examined how to support low comprehenders when these tools are unavailable or when the content does not afford a visual diagram. The implications of an intervention could be broad, as the similarity of results across Psychology and Biology suggests that finding ways to compensate for low comprehension has the potential to help students across subject areas.

Finding a way to support structure-building skills may be especially important when courses require students to make inferences or transfer knowledge to new situations. Inferences require learners to connect disparate ideas, a task that may be especially difficult when those ideas are modeled in separate structures rather than in one unified structure (Gernsbacher, 1997). Similarly, a unified structure would enhance one's ability to recognize similar patterns across disparate environments. Recognizing such similarities is a necessary prerequisite for transferring old knowledge to solve new problems (Gentner, 1983).

We close by emphasizing that we are not arguing that structure-building is the only cognitive skill that matters for academic success. Clearly, structure-building is just part of the cognitive toolkit the student brings to the classroom. For example, consider the most-researched individual difference in cognitive psychology, working memory. The ability to hold and manipulate information in memory is correlated with many skills, including measures of academic success such as self-reported university GPA (Gropper & Tannock, 2009), high school grades and ACT scores (Cowan et al., 2005), and SAT scores (Hannon & McNaughton-Cassill, 2011). Structure-building itself is modestly correlated with working memory ($r = .13$; Martin et al., 2015). However, working memory is a less flexible tool in that most attempts to train working memory have been relatively unsuccessful, when success is defined as transfer to other tasks (Unsworth, Redick, McMillan, Hambrick, Kane, & Engle, 2015). Structure-building may be a better candidate for an intervention, to the extent that structure-building could be improved (perhaps with self-explanation reading training; McNamara, 2004; although Gernsbacher's, 1997, suppression-deficit model may disfavor a training approach).

Structure building is also moderately correlated with reading comprehension ($r = .46$; Maki et al., 1994), another important skill that has been associated with academic success (Feldt, 1988). Tests for reading comprehension, such as the popular Nelson–Denny reading test (Brown, Nelson, & Denny, 1973), and the MMCB share surface feature similarities (e.g. reading short passages, answering multiple-choice questions about the passages), and the moderate correlation between the tests indicate that they measure some of the same variance. However, the Nelson–Denny and the MMCB target somewhat different skills, as is reflected in different patterns of results for text-presentation manipulations across low-skilled reading

(Nelson–Denny) comprehenders and low-skilled structure builders. McDaniel et al. (2002) found that increasing the difficulty of processing the words in a story (by deleting 18% of the letters throughout the text, which the reader had to fill in) decreased recall of the story for low reading comprehenders relative to an intact-text control, but did not compromise recall for low structure-builders (relative to an intact text control). In contrast, when the story was made more difficult by presenting the sentences in random order and requiring readers to rearrange the sentences into a coherent story, recall of the story improved for low-skilled structure-builders (relative to their relatively low performance in the intact text condition), whereas low-reading comprehenders' recall did not improve relative to the intact text condition, a condition in which their performance was relatively high (the idea is that the sentence arranging intervention stimulated low-structure builders to create a more organized representation then they would otherwise). These experimental dissociations converge with the theoretical assumptions that structure building reflects skill in creating coherent mental models and not necessarily front-end reading processes (such as lexical decoding), whereas standard reading tests are highly sensitive to the skills for front-end reading processes (Mason, 1978, 1980; Petros, Bentz, Hammes, & Zehr, 1990).

In sum, structure building goes beyond reading by measuring one's general ability to build a mental model of events and discourse, regardless of modality. In a classroom, students are expected to learn from not only readings, but also listening to lectures, viewing graphs and videos, participating in discussions, and many other tasks. Because of the multi-modality nature of educational contexts, a skill like structure-building that crosses modalities is likely a better target than reading comprehension for interventions, a possibility that should be explored in future research.

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REFERENCES

Baron, J., & Norman, M. F. (1992). SATs, achievement tests, and high-school class rank as predictors of college performance. *Educational and Psychological Measurement*, *52*, 1047–1055.

Brown, J. I., Nelson, M. J. B., & Denny, E. C. (1973). *The Nelson–Denny reading test*. Boston, MA: Houghton-Mifflin.

Bui, D. C., & McDaniel, M. A. (2015). Enhancing learning during lecture note-taking using outlines and illustrative diagrams. *Journal of Applied Research in Memory and Cognition*, *4*(2), 129–135.

Cahill, M. J., McDaniel, M. A., Frey, R. F., Hynes, K. M., Repice, M., Jiuqing Zhao, J., & Trousil, R. (2016). *Understanding the relationship between student attitudes and student learning*. Under Review.

Callender, A. A., & McDaniel, M. A. (2007). The benefits of embedded question adjuncts for low and high structure builders. *Journal of Educational Psychology*, *99*(2), 339–348.

Callender, A. A., & McDaniel, M. A. (2009). The limited benefits of rereading educational texts. *Contemporary Educational Psychology*, *34*(1), 30–41.

Cohn, E., Cohn, S., Balch, D. C., & Bradley, J. (2004). Determinants of undergraduate GPAs: SAT scores, high-school GPA and high-school rank. *Economics of Education Review*, *23*(6), 577–586.

Cowan, N., Elliott, E. M., Saults, J. S., Morey, C. C., Mattox, S., Hismjatullina, A., & Conway, A. R. (2005). On the capacity of attention: Its estimation and its role in working memory and cognitive aptitudes. *Cognitive Psychology*, *51*(1), 42–100.

Feldt, R. C. (1988). Predicting academic performance: Nelson–Denny Reading Test and measures of college students' study of expository prose. *Psychological Reports*, *63*, 579–582.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science*, *7*(2), 155–170.

Gernsbacher, M. A. (1997). Two decades of structure building. *Discourse Processes*, *23*(3), 265–304.

Gernsbacher, M. A., & Varner, K. R. (1988). *The multi-media comprehension battery*. Eugene, OR: Institute of Cognitive and Decision Sciences.

Gernsbacher, M. A., Varner, K. R., & Faust, M. E. (1990). Investigating differences in general comprehension skill. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *16*(3), 430.

Gropper, R. J., & Tannock, R. (2009). A pilot study of working memory and academic achievement in college students with ADHD. *Journal of Attention Disorders*, *12*(6), 574–581.

Hannon, B. (2014). Predicting college success: The relative contributions of five social/personality factors, five cognitive/learning factors, and SAT scores. *Journal of Education and Training Studies*, *2*(4), 46–58.

Hannon, B., & McNaughton-Cassill, M. (2011). SAT performance: Understanding the contributions of cognitive/learning and social/personality factors. *Applied Cognitive Psychology*, *25*, 528–535.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher*, *30*, 141–158.

Kalat, J. W. (1998). *Biological psychology* (6th edn). Pacific Grove, CA: Brooks/Cole Publishing Company.

Klymkowsky, M. W., Underwood, S. M., & Garvin-Doxas, R. K. (2010). Biological Concepts Instrument (BCI): A diagnostic tool for revealing student thinking. *arXiv:1012.4501*.

Lawson, A. E. (1978). The development and validation of a classroom test of formal reasoning. *Journal of Research in Science Teaching*, *15*(1), 11–24.

Lawson, A. E., Alkhoury, S., Benford, R., Clark, B. R., & Falconer, K. A. (2000). What kinds of scientific concepts exist? Concept construction and intellectual development in college biology. *Journal of Research in Science Teaching*, *37*(9), 996–1018.

Maki, W. S., & Maki, R. H. (2002). Multimedia comprehension skill predicts differential outcomes of web-based and lecture courses. *Journal of Experimental Psychology: Applied*, *8*, 85–98.

Maki, R. H., Jonas, D., & Kallod, M. (1994). The relationship between comprehension and metacomprehension ability. *Psychonomic Bulletin & Review*, *1*(1), 126–129.

Martin, M., Nguyen, K., & McDaniel, M. A. (2015). Structure building differences influence learning from educational text: Effects on encoding, retention, and metacognitive control. *Under Review*.

Mason, M. (1978). From print to sound in mature readers as a function of reader ability and two forms of orthographic regularity. *Memory & Cognition*, *6*, 568–581.

Mason, M. (1980). Reading ability and the encoding of item and location information. *Journal of Experimental Psychology: Human Perception and Performance*, *6*, 89–98.

McDaniel, M. A., Hines, R. J., & Guynn, M. J. (2002). When text difficulty benefits less-skilled readers. *Journal of Memory and Language*, *46*(3), 544–561.

McNamara, D. S. (2004). SERT: Self-explanation reading training. *Discourse Processes*, *38*, 1–30.

Petros, T. V., Bentz, B., Hammes, K., & Zehr, H. D. (1990). The components of text that influence reading times and recall in skilled and less skilled college readers. *Discourse Processes*, *13*, 387–400.

Savinainen, A., & Scott, P. (2002). The Force Concept Inventory: A tool for monitoring student learning. *Physics Education*, *37*(1), 45–52.

Unsworth, N., Redick, T. S., McMillan, B. D., Hambrick, D. Z., Kane, M. J., & Engle, R. W. (2015). Is playing video games related to cognitive abilities? *Psychological Science*, *26*, 759–774.

