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The Impact of Study Strategies on Knowledge Growth and Summative Exam Performance in the First Year of Medical School

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Abstract

Studying plays an important role in the academic success of medical students. There is a concern for the lack of empirical data related to what study strategies are the most productive for medical students to practice. In July of 2017, the incoming class of first year students (graduating class of 2021) at an allopathic medical school in the Midwestern United States (120 students) were given a survey at the beginning of medical school (August of 2017) to evaluate their study habits. We examined the relationship between the study strategies students reported to use and their academic performances measured by their success on the following standardized examinations: Comprehensive Basic Science Exam 1 (CBSE1), Comprehensive Basic Science Exam 2 (CBSE2), and the Step 1 exam, distributed by United States Medical Licensure Examiners (USMLE). Data suggest that students use a collective of deep processing strategies with an emphasis on contextualization to achieve greater gains on the CBSE exams and increase scores on the USMLE Step 1 exam.

Introduction

Effective study skills are important for learning (Jato et al. 2014, Mendezabal, 2013, Gettinger & Seibert 2002) as a great deal of learning happens outside of the classroom (Hussmann & O'Loughlin 2018, Mckee 2002). Many medical students erroneously focus on short-term memorization strategies which are defective in facilitating appropriate higher-order-thinking skills (Brown et al. 2014). The discrepancy in the relationship between studying and academic performance stems from the conditioned belief that learning comes from repeated exposure to material until it is mastered (Brown et al. 2014, Karpicke, 2009, Ward & Walker, 2008). This misconception inhibits effective metacognition (Brown, et al. 2014, Ward & Walker, 2008) warranting further research on study techniques that foster effective learning outcomes. Using data from students attending their first year of a medical program at a research-intensive university in the Midwestern United States, we estimate the proportion of time that medical students spend on deep and surface learning strategies and evaluate the impact these have on knowledge growth across the pre-clinical curriculum as well as score on the summative licensing exam that these students took after their pre-clinical phase.

Background

Popular study techniques such as massed practice and repetition are often seen as the best ways to master material. Medical students are accustomed to these types of practices and often rely on them when they study for exams such as the National Board of Medical Examiners (NBME) Comprehensive Basic Science Examination (CBSE), United States Medical Licensure Examination (USMLE) Step 1 exam. Data show that many of these routines are counterproductive, including surface-level strategies such as re-reading material, highlighting text, and repetition (Brown et al., 2014, Callendar & McDaniel, 2009, Gettinger & Siebert 2002). These strategies have shown limited effectiveness on licensure examinations as well (Mendezabal, 2013). Empirical evidence strongly supports that the most productive learning strategies require students to face a variety of challenges rather than the single study method of massed practice such as rereading and serial repetition (Brown et al., 2014 & Ward & Walker, 2008).

Empirical research challenges traditional views on study habits, in turn supporting study strategies such as flashcards, self-testing, and creating mental models using concept maps. These fall under the umbrella of retrieval practice and are found to have a positive impact on student learning (Brown et al 2014, Karpicke et al 2009). Ward and Walker (2008) also suggest that students construct their study routines to involve these types of approaches. In their study, the group of students who practiced techniques that evoked deep processing were more successful than their peers who relied on surface processing. Al-Kadri and colleagues (2011) also reported increased preparedness for assessments and clinical examinations when students integrated writing summaries and self-testing.

Although the distinction between deep and surface processing strategies, their potential to differentially impact learning, and data supporting the superiority of deep processing strategies on summative exam scores are well supported by the literature, more work is needed to understand: (1) how medical students combine study strategies into learning practices, and (2) the effectiveness of these learning practices in facilitating knowledge gains as measured by standardized test scores.

Methods

In 2017, an electronic survey was distributed via email to 120 first year medical students during orientation at an undergraduate medical school in the Midwestern United States. In this survey, students were asked to estimate the proportion of time they spent using eight different study strategies. These included surface processing strategies: (1) highlighting, (2) reviewing notes, (3) cramming, and (4) replaying lectures, as well as deep processing strategies: (5) flash cards, (6) concept maps, (7) self-quizzing, and (8) actively explaining material.

The responses from students in the program (n = 111) were reported as percent proportions of total time spent studying using different strategies. Subsequently, the scores from three standardized exams were recorded including: the NBME Comprehensive Basic Science Exam (CBSE 1 and 2 given at the end of Years 1 and 2, respectively) (Johnson et al. 2014), and the USMLE Step 1 exam (Step 1) (Glew, Ripkey, & Swanson, 1997). CBSE 1 was administered at the end of the first year, and CBSE 2 was administered at the end of their pre-clinical work, before the students took Step 1. To eliminate ceiling effects, normalized change in CBSE scores was calculated using the definition proposed by Marx and Cummings (2007).

Since the eight study strategies were used in combination, resulting in collinearity between the strategies, we utilized exploratory factor analysis (maximum likelihood estimation procedure with promax rotation) to reduce the eight study strategies into a smaller number of low-to-moderately correlated learning practices. Factors were retained based on the eigenvalue > 1 rule (Kaiser, 1960). The correlations between students' reported percent of time on each study strategy and their scores on each latent practice were inspected and used to create a qualitative definition of each practice. Standardized regression scores for the latent practices were saved and then regressed onto students' Step 1 score and CBSE normalized change score in order to deduce the effects of particular studying practices.

Results

Descriptive analysis of the study strategies (Table 1) indicates a strong preference for the surface processing strategy of reviewing notes (27% of the time on average) over the other strategies. The most popular deep processing strategy was self quizzing, which students on average did around 14% of time. Concept mapping and replaying were the least popular respective deep and surface processing strategies. Students engaged in these 11% and 5% of the time, respectively.

Table 1. Descriptive statistics for percentage of time reported for different study strategies, CBSE scores, and Step 1 score.

Classification	Measure	Mean	SD	Minimum	Maximum
Deep	Flashcards	11.63	14.149	0	70
	Concept Maps	10.59	11.937	0	50
	Self Quiz	14.29	11.769	0	65
	Explaining	11.71	9.155	0	50
Surface	Highlighting	10.88	14.971	0	90
	Reviewing Notes	27.09	18.478	0	90
	Cramming	8.59	9.628	0	40
	Replaying	5.31	7.262	0	30
Test Scores	CBSE 1	48.41	6.224	33	68
	CBSE 2	71.11	9.730	52	96
	Step 1	228.70	16.542	184	269

The exploratory factor analysis procedure extracted 4 factors based on the eigenvalue > 1 rule (Kaiser, 1960) which preserved 69% of the variation in the data (Table 2).

Table 2. Summary of the eigenvalues and the variance explained by each of the factors from Exploratory Factor Analysis exploring learning strategies that students tend to use together.

Factor (Practice)	Eigenvalue	% of variance	Cumulative % of variance
1	**1.832**	**22.956**	**22.956**
2	**1.348**	**16.848**	**39.804**
3	**1.315**	**16.434**	**56.238**
4	**1.004**	**12.554**	**68.792**
5	0.926	11.573	80.365
6	0.832	10.397	90.726
7	0.738	9.229	99.991
8	.001	.009	100.000

These described four low-to-moderately correlated learning practices (Tables 3 and 4). Practices 1 and 2 focus on use of deep processing strategies. Engagement in Practice 1 (Contextualization) was characterized by the tendency to engage with the strategies of concept mapping (0.498), self quizzing (0.518), and explaining material (0.394), and a strong disengagement with reviewing notes (-0.845). Engagement in Practice 2 (Flashcards) was characterized by a focus on using flashcards (0.931) and a moderate aversion to reviewing notes (-0.649). Practices 3 and 4 indicated focus on surface processing strategies. Practice 3 (Reviewing) focused on the strategy of reviewing notes (0.646) and a strong aversion to highlighting (-0.918). Practice 4 (Replaying) focused on the strategy of replaying (0.980) and a moderate aversion to reviewing notes (-0.404).

Table 3. Correlations between the study strategies and the four underlying practices.

Classification	Strategy	Practice 1 *Contextualization*	Practice 2 *Flashcards*	Practice 3 *Reviewing*	Practice 4 *Replaying*
Deep	Flashcards	-.002	**.931**	-.019	.088
	ConceptMaps	**.498**	-.102	-.023	-.065
	SelfQuiz	**.518**	.073	.069	.255
	Explaining	**.394**	-.021	.034	.014
Surface	Highlight	-.051	.005	**-.918**	-.122
	ReviewNotes	**-.845**	**-.649**	**.646**	**-.404**
	Cramming	-.028	-.156	.074	-.154
	Replaying	.144	.112	.062	**.980**

Pearson correlations (Table 4) indicate that the practice of Contextualization has a moderate positive correlation with the other practices. The practice of Reviewing shows a negative correlation with Flashcards, indicating that students may view these as being interchangeable practices.

Table 4. Correlations between the underlying practices, normalized change in the CBSE score, and Step 1 score.

	Practices				*Test Scores*	
	Contextualization	Flashcards	Reviewing	Replaying	CBSE change	Step 1
Contextualization	1	0.318**	0.310**	0.305**	0.237*	0.266**
Flashcards		1	-0.269**	0.243**	0.027	-0.045
Reviewing			1	-0.071	-0.125	-0.064
Replaying				1	-0.041	0.02
CBSE change					1	0.733**
Step 1						1

*α=0.05, **α = 0.01

Correlations between the practices and test scores (Table 4) indicate that the practice of Contextualization has a significant positive relationship with both normalized change in the CBSE score ($r = 0.237$, $p < 0.05$) and Step 1 score ($r = 0.266$, $p < 0.01$). The linear regression models (Table 5) show that the four practices together are predictive of normalized change in the CBSE score ($F_{4,106} = 2.152$, $p = 0.079$, $r^2_{adj} = 0.040$) and students' scores on the Step 1 exam ($F_{4,106} = 2.829$, $p = 0.028$, $r^2_{adj} = 0.062$). Controlling for the four practices within the same model, Contextualization was the only practice with a significant effect on Step 1 exam score ($B = 5.53$, $SE_B = 1.720$, $T = 3.215$, $p = 0.002$, $r_{partial} = 0.298$) and improvement in the CBSE ($B = 0.045$, $SE_B = 0.017$, $T = 2.552$, $p = 0.012$, $r_{partial} = 0.241$). A one standard deviation increase in application of contextualization strategies resulted in a 5.53 point average increase on Step 1, and an average normalized change increase of 0.045. Students who devoted more time to contextualization practices such as concept mapping, self quizzing, and explaining tended to learn more in the first year of their program and ultimately achieve higher measures on Step 1.

Table 5. Regression coefficients for effects of the four practices on normalized change in the CBSE and students' Step 1 score.

Measure	Effect	Estimate	SE	T	$r_{partial}$
CBSE Change	Intercept	.446	.015	28.901	
	Contextualization	0.045*	.017	2.552	.241
	Flashcards	-.008	.017	-.466	-.045
	Reviewing	-.011	.017	-.631	-.061
	Replaying	-.019	.017	-1.164	-.112
Step 1	Intercept	228.7	1.520	150.425	
	Contextualization	5.53**	1.720	3.215	.298
	Flashcards	-2.139	1.666	-1.284	-.124
	Reviewing	-.029	1.640	-.018	-.002
	Replaying	-1.50	1.628	-.924	-.089

*α=0.05, **α = 0.01

Discussion

According to the 2020 NRMP Program Director Survey (https://www.nrmp.org/main-residency-match-data/), 90% of programs cite USMLE Step 1 as a factor, with a mean importance rating of 4.0 (on a 5.0 scale), in selecting applicants to interview. This indicates Step 1 scores are important for students in getting residency program interviews. Starting in January 2022, Step 1 will have been converted to pass/fail (no numeric score). Step 2 CK and Step 1 score are highly correlated, so doing "well" on Step 1 is still important, even if the score is not reported. As of the 2020 NRMP Program Director Survey, Step 2 CK is cited by 78% of programs, with an average importance rating also of 4.0 of 5.0, in selecting applicants to interview. Given that conversion to pass/fail will make it more difficult to interpret an applicant's Step 1 result, we anticipate that the importance of Step 2 will only increase starting in 2022.

Medical students are life-long learners, and their profession necessitates the ability and willingness to keep up on most the recent research and clinical guidelines not only for their patients, but also to meet requirements for board certification and continuing education. Knowledge builds over time, so it is important for students to build a strong base their first year. We anticipate that this research will be useful in its illustration of the types of learning practices that lead to better knowledge retention and performance on standardized tests.

Conclusions

Our data show that the most effective study strategies involve deep processing such as concept mapping, self quizzing, and active explaining, and that these tend to be used together, not in isolation. Since students tend to be less familiar with deep processing study strategies such as active explaining and concept mapping, these strategies should be modeled by instructors within introductory medical courses. Since the medical profession is always changing, we are training our students to be life-long learners. It therefore makes sense for instructors to model how these strategies can be used in the field, and not just as a tool to prepare for examinations.

Increased formal integration of contextualization practices into medical programs is likely to improve program outcomes. Struggling students should be directed towards deep processing study strategies that focus on contextualization of information as opposed to recall methods.

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