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Individual Differences in Learning Exemplars Versus Abstracting Rules: Associations with Exam Performance in College Science

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Students may do well answering exam questions that are similar to examples presented in class. Yet, some of these students perform poorly on exam questions that require applying instructed concepts to a new problem whereas others fare better on such questions. Our hypothesis is that these performance differences reflect, in part, individual differences in learners' tendencies to focus on acquiring the particular exemplars and responses associated with the training exemplars (*exemplar learners*) versus attempting to abstract underlying regularities reflected in particular exemplars (*abstraction learners*). Using a web-based learning task developed in previous laboratory research, we differentiated students on this dimension, and then tracked their final exam performances in introductory chemistry courses. Abstraction learners demonstrated advantages over exemplar learners for transfer questions but not for retention questions. The results converge on the idea that individual differences displayed in how learners acquire and represent concepts persist from laboratory concept learning to learning complex concepts in science courses.

General Audience Summary

Instructors sometimes note that though students do well answering exam questions that are similar to examples (or problems) presented in class, a sizeable proportion of students flounder on exam questions that require applying instructed concepts to a new context (or problem). Yet, other students perform satisfactorily on these exam questions requiring transfer to a new context. To understand this difference, we suggest that some students orient toward learning an underlying abstraction of a concept, whereas other students focus on memorizing the set of problems (e.g., chemistry problems) or examples that illustrate the concept. In our study, we indexed students in a college chemistry course as either exemplar learners (memorizers) or abstractors, using a laboratory concept-building task (outside of the classroom). We found that learners identified as exemplar learners performed more poorly than learners identified as abstraction learners on chemistry exam problems requiring extrapolation (transfer) but not on exam problems that were very similar to class or homework problems. The present findings offer tantalizing evidence of an individual difference not yet identified in the academic-achievement literature that may have significant implications for students' learning outcomes in authentic educational situations.

Keywords: Individual differences, Abstraction, Exemplar learning, Student outcomes, Retention, Transfer

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For most college-level instructors (and likely for many pre-college level teachers), a core assumption seems to be that when students have learned the central concepts and constructs targeted by the curriculum, these students will be able to apply those concepts to new situations—situations beyond the particular context in which the concepts and constructs have been illustrated. This is reflected in frustration expressed by instructors (at least expressed to these authors) that though students do well answering exam questions that are similar to examples (or problems) presented in class, a sizeable proportion of students flounder on exam questions that require applying instructed concepts to a new context (or problem). Yet, other students perform satisfactorily on these exam questions requiring transfer to a new context. (This observation captures the state of affairs in the basic problem-solving literature as well; e.g., Gick & Holyoak, 1980.) In this article, we extend a theory based on laboratory concept learning to characterize the cognitive underpinnings of these differently performing students and attempt to predict student learning outcomes in a college chemistry course using a web-based instrument tied to the theoretical framework.

The Theoretical Framework and Basic Laboratory Findings

Our theoretical framework suggests that some learners orient toward learning an underlying summary representation of a concept (i.e., a rule, abstraction, or schema of the concept that captures the essential features of the variety of instances or examples that instantiate that concept), whereas other learners focus on learning the set of problems (e.g., chemistry problems) or examples that illustrate the concept along with the appropriate response to those examples (e.g., the response might be a category label, a particular set of problem-solution steps, or an expected outcome). This assumption is based on findings across a range of laboratory conceptual tasks: category learning (Craig & Lewandowsky, 2012; Little & McDaniel, 2015), function learning (McDaniel, Cahill, Robbins, & Wiener, 2014), multiple-cue prediction learning (Hoffman, von Helversen, & Rieskamp, 2014; Juslin, Olsson, & Olsson, 2003), and skill learning (Bourne, Raymond, & Healy, 2010). For these learning tasks, results show that some learners rely on exemplar representations and other learners build more abstract representations that underlie learning.

A further theoretical assumption is that in general, a learner's tendency toward an exemplar versus a summary-representation approach can be relatively stable across very different kinds of concept-formation tasks. Support for this hypothesis was reported in a study in which learners completed laboratory function learning and unrelated categorization tasks over the course of several weeks (McDaniel et al., 2014). Based on their extrapolation performance in the function-learning task, learners were identified as having oriented toward memorizing the particular training pairs (each input–output value pair) or as attempting to abstract the function rule (a bi-linear V-shape). Learners' approaches on the function-learning task significantly predicted their performance on a categorization task, such that those who displayed exemplar learning (i.e., memorizing particular training pairs) on the function-learning task showed categorization performance on the transfer test consistent with an exemplar representation, whereas those learners who displayed rule learning (abstraction) showed abstraction-driven categorization performance. Thus, individual differences in concept-building approaches tended to persist across quite different laboratory conceptual learning tasks.

In this study, we explore the provocative possibility that the individual differences in concept building revealed in a laboratory conceptual-learning task (function learning), at least in part, extend to students' learning tendencies in challenging and authentic educational contexts such as college science courses. Initial evidence supporting the idea that individual differences in concept building (as indexed by the laboratory learning task) are associated with learning (as assessed by exam performance) in chemistry courses was reported by Frey, Cahill, and McDaniel (2017). Students in college chemistry courses (General Chemistry 1, General Chemistry 2, and Organic Chemistry 2) completed the laboratory concept-building task (described in detail below) outside of the classroom, and based on their performance for this task were classified as relying on learning individual training instances to support their learning (for exposition, we term these individuals as *exemplar learners*) or relying on abstracting the general (functional) relation among the training instances (termed *abstraction learners*). In all three courses, overall exam performance for those students with an abstraction tendency was superior to performance for those with an exemplar-learning tendency. This association was present even when standard achievement and ability (e.g., ACT math scores) were taken into account.

The Present Study

We focused on learning in the General Chemistry 1 course, and we examined the following premise: students who display exemplar-learning tendencies on the laboratory function-learning task (described in detail in the next section) will also tend to focus on learning the particular example problems and solutions that are presented in class and homework (exemplar learners), whereas students who display tendencies to abstract in our laboratory task (i.e., learn the function rule) will also tend to attempt to abstract the principles and concepts that underlie the class and homework problems (abstraction learners). We reasoned that if this premise has merit, then the better performance displayed by abstraction learners relative to exemplar learners (as reported in Frey et al., 2017) should be uniquely observed on exam items that are not similar to class problems (i.e., questions requiring generalization; we label these *transfer* questions). The idea here is that performance on transfer questions is advantaged by more abstract representations of the principles and concepts that are illustrated in particular class examples and problems (see Gick & Holyoak, 1983, for supporting evidence in basic problem solving). By contrast, both abstraction learners and exemplar learners should perform equally well on course exam items that are similar to those presented in class (for convenience we label these *retention* questions); answering these kinds of exam questions should be

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