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Adult Learners Self-Derive New Knowledge through Integration of Novel Information and Prior Knowledge and Are More Successful with Reactivation

Jayantika Chakraborty
Clark University, JChakraborty@clarku.edu

Alena G. Esposito
Clark University, AEsposito@clarku.edu

MIND, BRAIN, AND EDUCATION

Adult Learners Self-Derive New Knowledge through Integration of Novel Information and Prior Knowledge and Are more Successful with Reactivation

Jayantika Chakraborty[1] and Alena G. Esposito[1]

ABSTRACT— Self-derivation through integration is the process of integrating novel facts and producing new knowledge never directly taught. Knowledge integration has been studied with the presentation of two novel facts. However, in educational settings, individuals are required to integrate new information with prior knowledge learned days, months, or years earlier. Prior knowledge robustly predicts learning outcomes, but less is known about self-derivation through the integration of new information with prior knowledge. Thus, in Study 1, we examined adults' ($n = 25$) memory integration of new facts with prior knowledge. The participants had 52% accuracy in self-derivation. In Study 2 ($n = 86$), we examined whether reactivating prior knowledge before the novel fact presentation facilitated self-derivation through integration with prior knowledge. Results indicated that performance was significantly higher for those whose prior knowledge was directly reactivated (55% accuracy) in comparison with the control group (42%). Pedagogical implications are discussed.

The primary goal of education is to support individuals in their quest to acquire knowledge. Developing an integrated base of semantic knowledge is crucial for academic and vocational success. Thus, it is necessary to integrate different episodes of learning and experiences with one's prior knowledge. We use many productive processes to build knowledge, such as analogy, deduction, induction (see Goswami, 2011, for review), and self-derivation through integration (see Bauer, 2021, for review). The emerging body of literature on self-derivation through integration has demonstrated that adults successfully integrate two related novel facts to self-derive new knowledge (e.g., Varga & Bauer, 2017; Wilson & Bauer, 2021). However, the corpus of research has primarily focused on testing self-derivation through integration of two novel facts provided to participants. Crucially, integrating new information with prior knowledge already pre-existing in memory has not yet been tested. Furthermore, it is unclear whether directly reactivating the memory of prior knowledge will facilitate the process of self-derivation. Thus, in the present study, we investigated whether college students self-derive new information with prior knowledge (Study 1) and whether reactivating prior knowledge facilitates self-derivation through integration with prior knowledge (Study 2).

Productive Processes and Self-Derivation through Integration

Productive processes of knowledge extension are prevalent in children, adults, and nonhuman animals (Bauer, King, Larkina, Varga, & White, 2012; Dusek & Eichenbaum, 1997; Schlichting, Zeithamova, & Preston, 2014; Varga & Bauer, 2017). One such mechanism to accumulate semantic knowledge is associative inference (Preston & Eichenbaum, 2013; Zeithamova, Schlichting, & Preston, 2012). In associative inference, participants are exposed to arbitrary

[1]Department of Psychology, Clark University,

Address correspondence to Jayantika Chakraborty, Department of Psychology, Clark University, Worcester, MA 01610; e-mail: jchakraborty@clarku.edu

pairs of words and images, such as carrot–bucket (AB) and bucket–ball (BC). The pairs share a common element, bucket. At test, participants are provided a probe "carrot" and must choose between "ball" and a distractor. The selection of "ball" indicates integration of the separate episodes based on the shared element (AC; Preston & Eichenbaum, 2013). Work with this paradigm has revealed that associative inference is an essential part of expanding our memory. However, it has limitations in that the items used are arbitrary, and it cannot be used to examine how new information connects with what is already known.

Self-derivation through integration is the process of integrating different episodes of learning in memory to derive novel, factual knowledge that was never explicitly taught (Bauer & Jackson, 2015; Varga & Bauer, 2017). For example, one may learn, "Mammals are the only group of animals with hair." In the second episode, one learns, "The scales of a pangolin are made of hair." By integrating these two facts, one can self-derive the understanding that *Pangolins are mammals*. This process enables us to create knowledge beyond what is explicitly taught. A significant body of empirical evidence points to this paradigm as a valid model for building semantic knowledge (see Bauer, Esposito, & Daly, 2020 and Bauer, 2021, for discussion). Self-derivation through memory integration has been tested in classrooms and laboratories and across different learning formats in both adults (e.g., Dugan & Bauer, 2022; Miller-Goldwater, Cronin-Golomb, Porter, & Bauer, 2021; Varga & Bauer, 2017; Wilson & Bauer, 2021) and children (e.g., Esposito & Bauer, 2019; Esposito, Lee, Dugan, Lauer, & Bauer, 2021). Moreover, the paradigm has been successfully used with academic content (e.g., Bauer et al., 2020), and the knowledge gains are retained over delays by both adults (e.g., Varga & Bauer, 2017) and children (e.g., Esposito, 2023). Importantly, performance predicts concurrent and longitudinal academic success in college students (e.g., Varga, Esposito, & Bauer, 2019). Thus, self-derivation through integration has shown to be a practical paradigm for understanding the process of memory integration with academic salience.

Prior Knowledge Supports Learning

Prior knowledge refers to all the knowledge one possesses in a particular domain (Schmidt, Rothgangel, & Grube, 2015). Prior knowledge robustly supports learning, explaining 30%–60% of individual variance in learning (see Tobias, 1994, for review). Prior knowledge significantly predicts self-regulated learning (Taub, Azevedo, Bouchet, & Khosravifar, 2014), learning over and above curiosity (Wade & Kidd, 2019), concept acquisition (Pazzani, 1991), and learning academic content (e.g., Rodd et al., 2012). Prior knowledge is thought to support learning because it provides an organized foundation of stored information in memory (see Bjorklund, 1987, for review). The organized nature of prior knowledge supports the retrieval of related information when learning new content. Thus, prior knowledge likely facilitates learning by freeing cognitive resources that would otherwise be expended in deliberate strategy use (see Esposito & Bauer, 2021, for discussion). Accordingly, those who have knowledge more easily gain additional knowledge. Witherby and Carpenter (2021) have explained this as a "rich-get-richer" effect.

Prior knowledge is related to successful self-derivation through memory integration. Varga, Cronin-Golomb, and Bauer (2022) examined the effects of prior knowledge on self-derivation by providing domain-relevant information to college students one to two days before the test session. The three conditions were (1) no-knowledge, (2) general information about the target domain, and (3) general information about the target domain including the fact necessary for self-derivation. Both the conditions providing prior knowledge about the target domain (2 and 3) had higher self-derivation performance than the no-knowledge condition. The study suggests a facilitative role of prior knowledge not only in learning directly provided content, but generating new knowledge not directly taught through the process of self-derivation through memory integration. However, prior knowledge in this study referred to new information provided to participants. Self-derivation through integration of new information with knowledge already possessed by participants (and not directly taught) has not yet been examined.

Memory integration of new information with prior knowledge could be challenging. Integrating with prior knowledge likely means that the integrable information was presented with varying time delays and through different mediums, both of which present integration challenges (e.g., Esposito et al., 2021). Although most of the research documenting these challenges has been with children, work with adults highlights the difficulty of temporal delays in integration. Dugan and Bauer (2022) examined adults' self-derivation performance of prescription medications after delays between presentations. They found that adults successfully self-derive new knowledge about prescription medications (roughly 40% correct in open-ended self-derivation). However, adults were less successful when there was a delay of approximately 24 h between the presentation of integrable materials and the testing session (33% accuracy—this did not differ from the control condition). Similarly, Zeithamova and Preston (2017) found that the temporal proximity of events facilitates the relational integration of overlapping memories. Participants were more accurate and efficient in inferring relations among memories learned on the same day relative to memories acquired across days. Thus, although prior knowledge facilitates learning new content, self-deriving new knowledge through integration of novel information with prior knowledge could prove challenging.

Reactivation of Prior Knowledge

Prior knowledge is related to learning; however, possessing prior knowledge is not enough. Learners must reactivate prior knowledge and link it to the new information to foster integration and generate novel understandings (Bransford & Johnson, 1972; Brod, 2021; Craik & Tulving, 1975; Shing & Brod, 2016). Thus, it is incorrect to assume that the availability of knowledge automatically benefits the integration of new information into congruent prior knowledge structures. If prior knowledge is not accessed appropriately, integration will fail (e.g., Beker, Jolles, Lorch, & Van Den Broek, 2016).

Prior knowledge reactivation refers to the process of recalling previously learned knowledge (Hattan, Alexander, & Lupo, 2023). More specifically, the process of prior knowledge reactivation entails recalling the knowledge one already possesses related to a specific experience, concept, or topic that is currently being considered or discussed (Hattan & Alexander, 2020). The literature documents multiple ways in which prior knowledge can be successfully reactivated, such as through open-ended prompts (e.g., Hattan & Alexander, 2018; Khataee, 2019; Lupo, Tortorelli, Invernizzi, Ryoo, & Strong, 2019), visual representations like concept maps (e.g., Amadieu et al., 2015; Hattan & Alexander, 2018), and extratextual activities like prereading texts and illustrations (e.g., Alvermann & Hague, 1989 and Kaefer, 2020, respectively). Prereading can be especially effective because it prepares learners for comprehension (Mandler & Goodman, 1982) and inferencing (Cain & Oakhill, 2007).

Prior knowledge reactivation could mitigate the challenge of integrating new knowledge with knowledge learned days, months, and years prior. Going by the cognitive availability framework of the cognitive load theory (Sweller, 1994), reactivation of prior knowledge would facilitate the availability of previously learned information in working memory. This would enable the effective linking of new and prior knowledge, thereby overcoming the challenges of temporally spaced learning.

In sum, prior knowledge can be a helpful tool for generative learning, but only if effectively used (see Brod, 2021). The literature suggests that the temporal gap between prior knowledge acquisition and learning new information is challenging to self-derivation (e.g., Dugan & Bauer, 2022). Reactivating prior knowledge may support self-derivation of new knowledge through integration with prior knowledge.

The Current Research

Self-derivation through integration has been predominantly studied in conditions where participants have been provided with both facts to integrate within a single experimental session (e.g., Bauer, Cronin-Golomb, Porter, Jaganjac, & Miller, 2021; Bauer & Jackson, 2015). As a result, there is a gap in understanding self-derivation through integration of new information with prior knowledge. Given the relation to academic performance, understanding the processes involved in self-derivation through integration with prior knowledge is crucial to supporting academic success. In the current research, we examined college-aged adults' self-derivation through memory integration of new content with prior knowledge (Study 1; $n = 25$). In Study 2, we examined whether reactivating prior knowledge (experimental group; $n = 43$) improves self-derivation performance relative to not (control group; $n = 43$).

We hypothesized that adults would integrate between new and prior knowledge to self-derive novel understandings (Study 1) and reactivating prior knowledge would lead to better self-derivation performance compared with the control group (Study 2).

STUDY 1

The primary purpose of Study 1 was to examine self-derivation through integration of new information with prior knowledge. We hypothesized that participants would effectively self-derive new information through the integration of prior knowledge with novel facts.

METHODS

Participants

Twenty-five undergraduate students participated in the current study ($M_{age} = 19.54$, $SD = 2.00$, 88% women, 10% men, 2% non-binary). The gender distribution in the sample approximates the gender distribution in the population the sample was drawn from (85% women). Our sample size was based on previous studies measuring self-derivation through integration with college students (e.g., Bauer & Jackson, 2015; Varga & Bauer, 2017; Wilson & Bauer, 2021). All participants in the study were undergraduate students at a private university in the northeastern United States. Participants were thanked for their time with a choice between a $5 gift card and a $5 book donation to a local elementary school. The University Institutional Review Board (IRB) reviewed and approved all the recruitment protocols and procedures for the study. Written consent was obtained from each participant.

Materials

We developed 14 expository paragraphs containing facts about 14 different animals. There were six uncommon, unknown animals (e.g., matamata) and eight commonly known animals (e.g., snake; see Table 1). The paragraphs

Table 1
List of Animals and their Taxonomic Classification

Animal Category	*Known animals*	*Unknown animals*
Mammals	Pig, giraffe	Lowland-streaked tenrec, pangolin
Reptiles	Snake, alligator, iguana	Matamata
Amphibians	Frog	Olm, axolotl
Birds	Chicken, eagle	Lophorina

about unknown animals were designed to provide key facts that, when integrated with prior knowledge about animal taxonomy, would permit self-derivation of the correct animal taxonomic group. All expository paragraphs were comparable in length (an average of 75 words for both known and unknown animals). All paragraphs also had comparable ease-of-reading scores ($M_{\text{grade}} = 8.12$, range = 5.1–14.1 for known animals; $M_{\text{grade}} = 9.97$, range = 7.3–13.7 for unknown animals; the name of the unknown animal, being rare, increases the reading score) on the Flesch Kincaid calculator used to assess ease of reading. There was an average of two target words/phrases in each paragraph that cued the correct taxonomic category of each animal (e.g., "cold-blooded" and "covered in bony plates" for a reptile). Examples of expository paragraphs are provided in Supplementary Materials.

The unknown animals were chosen based on lack of familiarity. Unknown animals were chosen with the help of pilot testing within the same community drawn from the same participant pool. Animals were only included if identification of the taxonomic category in a forced-choice test was below chance. This was crucial as it demonstrated that, at the aggregate level, the general population lacked prior knowledge for the correct taxonomic classification for the unknown animals. This is necessary because testing for knowledge of unknown animals prior to the integration protocol could potentially lead to priming participants by prompting specific attention to animal taxonomy, thereby contaminating our assessment of spontaneous integration with prior knowledge. The pilot data were collected as a part of university classes prior to the study commencing and we do not have the IRB permit to share the data.

In contrast to unknown animals, we are able to share the details of a separate pilot study demonstrating that known animals were easily taxonomically categorized. Pilot participants ($n = 40$) could accurately report the basic taxonomical characteristics of mammals, birds, reptiles, and amphibians at greater than 90% accuracy for all animals and pilot participants. In the pilot testing, we asked participants to select the correct features for mammals, birds, amphibians, and reptiles from a pool of 12 options. The pool of options contained three choices that categorically applied to each animal group. For example, for mammals, the choices were "drink mothers' milk," "have hair," and "warm-blooded." Therefore, each participant could get a maximum score of 3 for each animal group. Results demonstrated that the mean score for mammals was 2.45 ($SD = .59$); the mean score for birds was 2.93 ($SD = .27$); the mean score for reptiles was 2.76 ($SD = .48$); and the mean score for amphibians was 2.4 ($SD = .55$). Thus, average college students possessed the prior knowledge needed for subsequent self-derivation through integration with the novel facts.

Measure

Animal taxonomy test

Participants were asked which of the four taxonomic categories (mammals, birds, reptiles, or amphibians) each animal (known and unknown) belonged to. Eight asked the taxonomic category of known animals, and 5 asked the taxonomic category of unknown animals (because of experimenter error, the direct question asking the category of the animal lophorina was left out). The known animal questions served as an individual measure of knowledge on animal taxonomy. The unknown animal questions were the test for self-derivation through integration of new information with prior knowledge.

Procedure

Participants met over Zoom for approximately 35 min with a trained research assistant who explained the tasks using Zoom's screen-sharing feature with remote access. Participants read each expository paragraph about each animal twice in a row, with a 5-min buffer task halfway through. There were four randomized orders of fact paragraphs to minimize order-effect bias. An equal number of participants were assigned to each order. After reading the final set of paragraphs, participants completed another 5 min of buffer tasks and activities. Participants were then asked to complete the animal taxonomy test through Qualtrics.

RESULTS

The data were distributed normally for correct taxonomic classification of known and unknown animals (See Table 2). The correlation between the accuracy of known and unknown animals was not statistically significant ($r = -.274$, $p = .18$). The average accuracy score of known animals was 93.5% ($SD = .09$), which was significantly above chance (25% expected by chance; $t(25) = 37.02$; $p < .001$). Self-derivation

Table 2
Study 1 Descriptive Statistics

Animal group	M *(SD)*	*Skewness*	*Kurtosis*
Unknown	52.80 (25.85)	−.57	−.21
Known	93.50 (9.43)	−1.14	−.163

through integration of prior knowledge with novel facts average accuracy score was 52.8% ($SD = .26$), also significantly above chance (25% expected by chance; $t(25) = 5.48$; $p < .001$).

DISCUSSION

The aim of Study 1 was to examine whether college-aged adults successfully self-derive new information through the integration of prior knowledge with novel facts. Results indicate that participants could self-derive the correct taxonomic categories of unknown animals at above-chance levels. Self-derivation through integration performance was at 52.8% accuracy. This finding is consistent with results from other adults' forced-choice self-derivation performance using different protocols and procedures (e.g., 45% in Varga & Bauer, 2017; 56% in Bauer & Jackson, 2015). The results provide the first evidence for self-derivation through integration of novel information with prior knowledge already existing in participant memory.

Known animals were correctly classified taxonomically at over 90% accuracy, providing further support that participants had a basic understanding of animal taxonomy. Interestingly, accuracy for known and unknown animal taxonomy was not significantly correlated. This may be because of the different knowledge being tested. Known animals tested knowledge that participants already had in memory and likely required little effort. Unknown animals required self-derivation through integration, a cognitively challenging task that as already discussed required more than possessing knowledge.

These results are promising and also provide the impetus to test whether they can be improved with reactivation of prior knowledge before exposure to the novel facts. In Study 2, we tested whether reactivating participants' prior knowledge through a short reading about animal categories improves self-derivation performance, thereby potentially understanding ways to make new learning less challenging.

STUDY 2

The primary purpose of Study 2 was to examine whether reactivating prior knowledge would facilitate self-derivation through integration. We hypothesized that participants in the reactivation condition would have better self-derivation through integration performance compared with a control group.

METHOD

Participants

The participants were 86 ($M_{age} = 20.16$, $SD = 1.47$; 46% women, 19% men, 4% non-binary, 31% unreported) undergraduate students drawn from the same undergraduate student body as in Study 1. Study 2 was initially designed to have two subconditions under experimental and control conditions each. The sample size for each condition was 25 for each subcondition (same as Study 1). This sample size was based on previous self-derivation studies (e.g., Bauer & Jackson, 2015; Varga & Bauer, 2017, Study 1; Wilson & Bauer, 2021) with medium to large effect sizes. In data analyses, we found that the subconditions for both experimental and control groups did not significantly differ from each other. Thus, we collapsed the data from the subconditions for each group, resulting in a sample size of 86 divided between the experimental group (n = 43) and control group (n = 43). We have now included this explanation and additional information in the Supplementary Materials.

Participants were thanked as in Study 1. The University Institutional Review Board (IRB) reviewed and approved all the recruitment protocols and procedures for the study. Written consent was obtained from each participant.

Materials

The materials were the same 14 expository paragraphs about known and unknown animals from Study 1. There were two additional passages, one for each between-person condition. These passages were designed to contain commonly known information. The reactivation condition (experimental) read a passage about animal taxonomy (words = 113). The control group read a passage about cloud categorization (words = 105). The reactivation passage for the experimental group contained information derived from elementary science curriculum. The information is extensively studied across grade schools and reiterated in state-required high school biology courses. The above-chance performance by our pilot study participants in selecting the correct features of mammals, birds, reptiles, and amphibians confirmed that college students drawn from the same sample, in general, are aware of different animal taxonomic features of common animal groups. Thus, the passage served to reactivate prior knowledge rather than teach new information. The passage on clouds was designed to have a similar amount of information in similar scientific language. However, the passage on clouds was unrelated to animal taxonomy and should, therefore, not reactivate prior knowledge relevant to the integration task. The passages are provided in Supplementary Materials.

Measure

Animal Taxonomy Test: As in Study 1, participants were asked which of the four taxonomic categories (mammals, birds, reptiles, or amphibians) each animal (known and unknown) belonged to. Eight asked the taxonomic category of known animals, and 6 asked the taxonomic category of unknown animals. The former served as an indicator of individual animal taxonomy knowledge and the latter as the self-derivation through integration test.

Procedure

The procedure mirrored Study 1 with three exceptions. First, participants were randomly assigned to either the experimental or control group. Second, participants read the passage assigned to their condition (animal taxonomy or clouds) prior to beginning the Study 1 protocol. Third, a separate research question examined the time of the self-derivation test. Here, self-derivation through integration testing varied from the same session as fact presentation to three days later. There were no differences in performance based on test timing, so data were collapsed to ensure sufficient power for the current research questions (See Supplementary for more information).

RESULTS

The means and standard deviations for each group are reported in Table 3. As shown, the data were distributed normally. Known animal taxonomic group identification was above 90% accuracy for both the experimental and control group, representing above-chance performance [$t(42) > 42.4$; $p < .001$ and $t(42) = 29.28$; $p < .001$, for experimental and control groups respectively]. A t-test revealed that the experimental and control conditions did not differ for the identification of known animal taxonomic category, $t(84) = 1.15$; $p = .25$. Self-derivation through integration of the unknown animals was also above-chance performance in both the experimental and control conditions [$t(42) > 6.80$; $p < .001$ and $t(42) = 4.38$; $p < .001$, for experimental and control groups respectively]. There was a significant correlation between known animals' and unknown animals' accuracy scores for the experimental group ($r = .438$, $p = .003$) and the control group ($r = .563$, $p < .001$).

To test the hypothesis that reactivation of prior knowledge would facilitate self-derivation through integration, we conducted a t-test to examine differences between our experimental and control conditions in unknown animal taxonomic classification. Consistent with our hypothesis, the t-test revealed a significant difference between the experimental and control groups such that those in the experimental group who read the animal taxonomy reactivation passage had significantly better self-derivation through integration performance compared with the control condition that read the expository paragraph about clouds, [$t(84) = 2.16$; $p = .034$; $d = .47$].

DISCUSSION

The main aim of Study 2 was to understand whether reactivating participants' prior knowledge facilitates self-derivation through integration of a novel fact with prior knowledge. As hypothesized, reactivation of prior knowledge resulted in the experimental group performing significantly better (at 55% accuracy) than the control group (42% accuracy) in self-deriving new knowledge through integration of a novel fact with prior knowledge.

GENERAL DISCUSSION

The current work explored whether adults effectively integrate new information with prior knowledge to self-derive novel understandings. We found that college-aged adults are able to successfully self-derive new information through

Table 3
Study 2 Descriptive Statistics

	Unknown animals			*Known animals*		
Group	M *(SD)*	*Skewness*	*Kurtosis*	M *(SD)*	*Skewness*	*Kurtosis*
Experimental ($n = 43$)	55.03 (28.98)	.335	−1.102	94 (10.69)	−2.430	7.00
Control ($n = 43$)	42.24 (25.81)	.19	.01	91 (14.71)	−1.10	4.04

integration with prior knowledge and are doing so after one exposure to the previously unknown information. Promisingly, reactivation of prior knowledge before exposure to the new information facilitated self-derivation through integration.

Understanding the process of memory integration as measured by the self-derivation paradigm is crucial to understanding why memory integration with new knowledge consistently poses a challenge, and also why reactivation of prior knowledge plays a facilitative role. The ERISS model (see Bauer, 2021, for discussion) outlines the component processes of self-derivation. According to the model, five component behavioral processes are involved in the self-derivation of new knowledge: encoding, reactivation, integration, selection, and self-derivation. In the first process, learners encode the new content in a learning episode (e.g., Pangolin scales are made of hair). Upon successful encoding, one reactivates the collection of memory traces that relates to the new piece of content (e.g., Mammals are the only animals with hair). Third, one integrates the information from different memory traces (e.g., all context-relevant information about hair and mammals). Fourth, one selects the relevant memory trace upon a cognitive demand (e.g., Which animal group does the pangolin belong to?). Fifth, one self-derives the new knowledge that is contextually appropriate (e.g., Pangolins are mammals). Therefore, individuals must expend considerable cognitive effort at each stage to self-derive a novel understanding.

In the context of self-derivation with prior knowledge, reactivation of one's prior knowledge base that relates to newly encountered memory content is crucial but also presents considerable challenges. As a reminder, the temporal delays in the presentation of integrable materials and different modes of instruction (texts, graphs, illustrations, etc.) make it challenging for learners to reactivate prior knowledge that is congruent and contextually relevant to the learning situation (e.g., Dugan & Bauer, 2022; Esposito et al., 2021). In the self-derivation context, the importance of reactivation of prior knowledge is supported by the framework of cognitive availability (Sweller, 1994) that posits associated memory traces are simultaneously reactivated to promote memory integration. This means, to overcome the outlined challenges to self-derivation, relevant prior knowledge must be made cognitively available in working memory. The results of Study 2 support that reactivating relevant and congruent prior knowledge affords a higher degree of accurate self-derivation.

Interestingly, the correlation between known and unknown animal taxonomy performance was significant for both the experimental and control groups in Study 2. Having greater knowledge about animal taxonomy (as represented by known animal classification) should, in theory, facilitate learning the unknown animal taxonomy through self-derivation. However, this correlation was not significant in Study 1. This may be because of the larger sample size in Study 2, which allowed for greater statistical power. The results of Study 2 support our hypothesis that possessing a strong foundation of prior knowledge can lead to effective self-derivation of new knowledge, thereby highlighting the centrality of prior knowledge in new learning. The inconsistency in the results between studies highlights an area for additional exploration.

The current study is not without limitations. The primary limitation is that the expository reading passages were difficult and could have potentially influenced students' self-derivation process either because they were difficult to encode or because the difficulty might be a barrier to recognizing the relation with prior knowledge. Additionally, the reactivation passages were information dense, which may have factored into how well they activated prior knowledge. Variations in the passage's reading level and information density are an important direction for future research. Second, the information presented was focused on animal taxonomy and might not necessarily generalize to other content areas. Indeed, evidence with children indicates science is a particularly difficult content area for self-derivation through derivation (Bauer et al., 2023). Third, although we ensured through pilot testing that the unknown animals were indeed unknown, individual differences are expected. Thus, it is possible that some participants had prior knowledge of one or more of these rare animals, which means that they did not integrate novel information with prior knowledge. Finally, the study was with college students and, therefore, might not generalize to other age groups or learning situations. These limitations also provide interesting directions for future research.

One of the greatest challenges in higher education is helping students integrate their learning (Huber & Hutchings, 2004). The capacity to draw connections is essential to the conduct of personal, professional, and civic life and is the core of both liberal and STEM education (Huber, Hutchings, Gale, Miller, & Breen, 2007). However, as with many problem-solving activities, students can get preoccupied with the task content and lose sight of the disciplinary content (Reiser, 2004). In light of this, the current work contributes two robust findings. First, college students can successfully grow their knowledge base with self-derivation through integration of new content with prior knowledge. Second, in line with research spanning two centuries that supports prior knowledge reactivation in new learning (Alexander, Kulikowich, & Schulze, 1994; Ausubel, 1968; Kant, 1787/Kant, 1963; Wetzels, Kester, & Broers, 2011), reactivating students' prior knowledge can facilitate not only learning new content, but expanding beyond what is directly taught to self-derivation of new knowledge through integration of novel facts with prior knowledge. These results provide a window of optimism to effectively counter the challenges students face in higher education settings.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Data S1. Supporting Information.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

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DATA AVAILABILITY STATEMENT

The datasets analyzed in the current studies are available from the corresponding authors on reasonable request. Neither of the studies was preregistered.

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