How Do College Students Use Digital Flashcards During Self-Regulated Learning?

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This article has been accepted for publication in *Memory*, published by Taylor & Francis. The article was accepted on March 22, 2022.

This is an original manuscript of an article published by Taylor & Francis in *Memory* in 2022, to be available online at: https://dx.doi.org/10.1080/09658211.2022.2058553

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We have no known conflict of interest to disclose.

Inez Zung and Steven C. Pan changed institutional affiliations from UCLA to their current institutions in the duration of this project, which is reflected in their listed affiliations above.

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Data and materials for this study are archived at the Open Science Framework at: https://osf.io/5g4ur/

Abstract

Over the past two decades, digital flashcards—that is, computer programmes, smartphone apps, and online services that mimic, and potentially improve upon, the capabilities of traditional paper flashcards—have grown in variety and popularity. Many digital flashcard platforms allow learners to make or use flashcards from a variety of sources and customise the way in which flashcards are used. Yet relatively little is known about why and how students actually use digital flashcards during self-regulated learning, and whether such uses are supported by research from the science of learning. To address these questions, we conducted a large survey of undergraduate students (n = 901) at a major U.S. university. The survey revealed insights into the popularity, acquisition, and usage of digital flashcards, beliefs about how digital flashcards are to be used during self-regulated learning, and differences in uses of paper versus digital flashcards, all of which have implications for the optimisation of student learning. Overall, our results suggest that college students commonly use digital flashcards in a manner that only partially reflects evidence-based learning principles, and as such, the pedagogical potential of digital flashcards remains to be fully realised.

Keywords: digital flashcards, online learning technologies, distributed practice, retrieval practice, self-regulated learning

How Do College Students Use Digital Flashcards
During Self-Regulated Learning?

Today's students have access to a wide array of educational technologies, including modern implementations of traditional learning tools. For instance, digital flashcards (also called computer flashcards, electronic flashcards, or virtual flashcards) duplicate the functions of conventional paper flashcards (i.e., index cards that typically contain related information on each side of the card, such as a concept and its explanation or a practice problem and its worked answer), including the ability to engage in self-testing by using one side as a prompt to recall information on the reverse side. However, unlike paper flashcards, digital flashcards are typically created, stored, and used via websites, smartphone apps, and/or other programmes. Digital flashcards also offer more functions than paper flashcards, including greater control over one's progress during learning, the ability to present different types of materials (e.g., multimedia), options to configure the order and frequency of flashcards (e.g., using spaced repetition algorithms), easy removal or retention of individual cards for further study (via "dropping" or "starring" functions), built-in games, greater varieties of practice questions, and more.

Since their commercial debut over two decades ago (e.g., Texas Instruments, 2001), digital flashcards have become increasingly popular and are now used across a wide range of devices. More than a dozen systems are available ("List of flashcard software," 2021), and many continue to add features. For instance, one of the most popular digital flashcard services, Quizlet, boasts over 50 million active users per month (Glotzbach, 2019) and has expanded from a solely web-based platform to both web-based and mobile applications, plus added games and different usage modes. There is little doubt that digital flashcards will, over time, continue to gain even more users and become increasingly differentiated from paper flashcards.

Given their growing complexity, the use of digital flashcards to engage in *self-regulated learning*—that is, when an individual manages their learning entirely, starting from the planning of learning activities and extending through evaluating the effects of those activities (Bjork et al., 2013; Winne & Hadwin, 1998)—presents an increasingly challenging set of decisions for many students. Students must decide which platform to use, which materials to learn, and how to make or obtain flashcards. After the digital flashcards are ready, they must decide which learning activities to engage in—for instance, self-testing, games, or simply reading or reviewing. They must also decide the timing, quantity, frequency, and setting of flashcard use (e.g., two weeks before an exam, large sets or small sets, daily or weekly, during their commute, etc.). Finally, as

they cycle through each flashcard, students may choose whether to turn the flashcard around and view the reverse side (which, if self-testing is used, provides an opportunity to check the accuracy of one's responses) or simply move on, and if starring or dropping functions are available, whether to prioritise some flashcards and/or drop others from further study. Importantly, given that research into digital flashcards is still in its infancy (cf. Altiner, 2019; Dizon & Tang, 2017; Hung, 2015; Sage et al., 2016; Sage et al., 2019), relatively few evidence-based recommendations for their use currently exist, and as such, students often have to rely on little more than intuition in making such decisions. Further, although a recent review of flashcard programs suggest that they may facilitate effective learning strategies such as successive relearning (a combination of retrieval practice and spacing; Dunlosky & O'Brien, 2020), researchers have yet to thoroughly investigate how students actually use these programs.

Of the many ways that digital flashcards can be used, which do college students, whom are among the most common users of such flashcards, tend to prefer? Why do they prefer doing so? Are these preferences stable or altered by metacognitive judgments or study contexts? We addressed these questions by conducting the first-ever large-scale survey of digital flashcard use at a major public university. Our survey explored such issues as how digital flashcards are made or obtained (e.g., types of content; self-made vs. pre-made flashcards), how students use and practice with digital flashcards (e.g., using dropping functions; types of learning activities), potential uses of digital flashcards with peers, and whether common usage patterns align with four potentially effective ways to use flashcards, all of which are rooted in evidence-based learning research (Dunlosky et al., 2013; Pan & Bjork, 2022; Weinstein et al., 2018): self-testing, correct answer feedback, spacing out learning, and generating answers.

Potentially Effective Uses of Flashcards for Learning

Educators and researchers often recommend using flashcards for learning because they can facilitate beneficial self-testing (e.g., Smith & Weinstein, 2016), which capitalises on the well-established *retrieval practice effect*. The retrieval practice effect, also known as the testing effect, is the phenomenon wherein taking a memory test on some material improves long-term retention of that material relative to non-retrieval-based methods such as restudying (e.g., Bjork, 1975; Carrier & Pashler, 1992; Roediger & Karpicke, 2006). Although the retrieval practice literature does not focus on flashcards per se, it is plausible that its findings can be extrapolated to flashcard use given that the retrieval practice effect is robust across different test formats and methods of engaging in self-testing (e.g., Rowland, 2014). Surveys of paper flashcard use

indicate that self-testing is a common activity among students when using this study tool (Wissman et al., 2012). The present survey investigated whether similar patterns occur for digital flashcards.

Beyond the retrieval practice effect, flashcards can be also used to confer the benefits of *correct answer feedback*. Given that flashcards typically contain a cue on one side and a definition or answer on the reverse side, students can attempt to productively retrieve the information cued by the front of the flashcard before flipping it over to receive feedback. The retrieval practice effect is enhanced by correct answer feedback (e.g., Pan, Hutter, et al., 2019; for review see Rowland, 2014), as it can help learners to maintain their own correct response (Butler et al., 2008) or adjust their response if they made errors (Kang et al., 2007). However, surveys of paper flashcard use suggest that about one-third of students infrequently check the back of their flashcards after testing themselves (Wissman et al., 2012), and in one empirical study, students even dropped flashcards from study after no correct retrievals if they felt so unduly confident in their retrieved response that they declined to check the back of the flashcard (Kornell & Bjork, 2008). The present survey explored the possibility that feedback may also be underutilised among users of digital flashcards.

Another potentially effective way to use flashcards is by spacing out study sessions and items. The *spacing effect* refers to the retention advantage when learning events are spaced apart in time as compared to when they are massed together (e.g., Cepeda et al., 2006; Donovan & Radosevich, 1999). Spacing with digital flashcards has been shown to enhance learning: Kornell (2009) investigated spacing both within and between learning sessions when using a web-based study programme to learn vocabulary word-pairs. In the first experiment exploring within-session spacing, participants studied one large set of flashcards (spacing) or four smaller sets (massing), with the number of repetitions for each item across conditions held constant. Those in the spacing condition performed better on a final cued recall test than those in the massing condition. A second experiment added between-session spacing by having participants study across four days, either by using the large set twice each day (spacing) or using one small set eight times each day (massing), and the addition of between-session spacing enhanced the spacing effect. This benefit of spacing held even when all participants were given a final review session during which both conditions restudied all the word-pairs twice. Kornell's findings provide potent evidence for how flashcards might be used to implement spacing: Students can use larger flashcard sets rather than splitting items into smaller sets, and do so across multiple

days. They might also avoid dropping flashcards from further study, thereby maintaining the spacing between items and strengthening learning via additional practice. However, students do not typically capitalise on the potential benefits of spacing when using paper flashcards, as they often prefer to use smaller flashcard sets when studying and believe that smaller sets are better for learning than larger flashcard sets (Wissman et al., 2012). (For a more detailed discussion and comparison of implementing successive relearning in different flashcard programs, see Dunlosky & O'Brien, 2020). In the present survey, we addressed whether similar patterns occur for digital flashcards, and moreover, whether common digital flashcard features are used in ways that promote or not promote spaced learning opportunities.

Finally, flashcards can be used to capitalise on the benefits of generation. The *generation effect* refers to the finding that material that is generated (e.g., producing synonyms) is better remembered than material that is simply read (e.g., Bertsch et al., 2007; Slamecka & Graf, 1978). This effect has been demonstrated with word pairs and fragments (e.g., Gardiner, 1988; Jacoby, 1978) as well as more educationally relevant materials such as outlines and study questions (e.g., Foos et al., 1994). The generation effect holds even when students are asked to generate answers to mathematical operations with the answer present for reference (Crutcher & Healy, 1989). Generation can occur with flashcards if students adapt information from their notes or textbook to put on their own cards—that is, when students self-generate flashcard content. In a recent series of experiments, Pan et al. (2022) found that learners exhibited better memory and transfer performance when asked to create digital flashcards before using them, as opposed to using already pre-made digital flashcards. The present survey addressed whether students are willing to generate their own digital flashcards or are deterred by the time and effort needed to do so.

Potential Factors Influencing Digital Flashcard Use

Flashcards are often used in informal, self-regulated settings outside of the classroom, where choices that result in ineffective or inefficient learning are common (e.g., Bjork et al., 2013; Dunlosky et al., 2013). According to the *desirable difficulties* framework (Bjork, 1994), some learning activities (e.g., retrieval practice) slow immediate increases in performance and appear to reduce learning during acquisition, but paradoxically improve learning over the long-term, whereas other learning activities (e.g., restudying) appear to ease the acquisition of new information but may not be effective over the long-term. As students often conflate learning and performance (Soderstrom & Bjork, 2015), they may opt for learning activities and methods that increase short-term performance rather than durable learning. Students' preference for smaller

sets of paper flashcards (despite knowing that spaced study is better than massed study, as in Wissman et al., 2012) is consistent with that account, and similar patterns might also be observed with digital flashcards. Other factors that may lead to ineffective uses of digital flashcards include inaccurate metacognition even when holding accurate knowledge about principles of learning, a lack of knowledge about and experience with managing one's own learning, and individual differences in academic ability (which are the basis for a series of exploratory analyses discussed later in this manuscript), among other characteristics.

Some features unique to digital flashcards may also influence whether students make effective learning decisions and/or engage in successful learning activities. Common such features are summarised in Table 1. On the positive side, digital flashcard platforms can be designed or configured to, for example, force users to check the backs of their flashcards after attempting retrieval (e.g., Anki). Some flashcard services also capitalise on the spacing effect by integrating algorithms that take the decision-making power away from users, thereby forcing items to be revisited regardless of whether a user feels they have learned them adequately. In addition, dropping flashcards can be prevented by design in digital formats, which could benefit learning by enforcing repeated testing and inter-item spacing. On the negative side, however, if the aforementioned features are not enabled, then users may not experience any of the associated benefits. Moreover, some digital flashcard features, such as dropping functions, could be used to prematurely terminate the use of specific flashcards, which may reduce learning. Finally, the widespread availability of pre-made digital flashcards could also deprive users of the potential benefits of generating their own flashcards. To address these considerations, the present survey investigated potentially productive and unproductive uses of common digital flashcard features.

More generally, digital flashcards may have some inherent advantages over paper flashcards that help users learn more effectively. For example, Ashcroft et al. (2016) found that Japanese university students learning English as a second language exhibited greater vocabulary learning gains after using digital flashcards compared to using paper flashcards, and suggested that the digital format may have benefited these students more due to the greater variety of activities offered by the flashcard service used in the experiment (Quizlet) and the greater level of control that the service exerted over participants' learning activities. All of these digital flashcard features may have aided in sustaining engagement and motivation. However, whether such benefits of digital flashcards generalise to other materials remains to be determined (for other comparisons of digital versus paper flashcards, see Dizon & Tang, 2017; Sage et al., 2016;

Sage et al., 2019), and more broadly, how digital flashcard platforms may support self-regulated learning in ways that paper flashcards cannot remains to be determined. Accordingly, the present survey included questions comparing beliefs and practices pertaining to digital versus paper flashcards.

Method

Participants

During the survey period, which began on September 23, 2020, and closed on January 30, 2021, 988 undergraduate students from the subject pool at the University of California, Los Angeles (UCLA) accessed the survey. Of those students, 901 respondents (81%, n = 729 women; 18%, n = 160 men; 0.67%, n = 6 non-binary; 0.11%, n = 1 pangender; 0.22%, n = 2 other; 0.33%, n = 3 chose not to respond) completed the survey in its entirety and received partial course credit. We did not explicitly collect data on year at UCLA; however, the age breakdown of participants suggests that approximately 64% of the sample was likely underclassmen and 36% of the sample was likely upperclassmen (M_{age} = 20.1 years). Some (4.4%, n = 40) of respondents reported majors in the humanities (e.g., linguistics, English), 7.3% (n = 60) in the social sciences (e.g., political science, education, public affairs), 72.5% (n = 653) in the life sciences (e.g., biology, psychology), 4.3% (n = 39) in the physical sciences (e.g., chemistry, mathematics), 0.7% (n = 6) in engineering (e.g., bioengineering, computer science), and 0.9% (n = 8) in visual and performing arts (e.g., film, dance). Nineteen respondents (2.1%) reported their major as undeclared, 0.7% (n = 6) as other, 6.8% (n = 61) as two or more, and 0.3% (n = 3) chose not to respond. A full list of majors represented among the sample is at this study's Open Science Framework (OSF) repository. Additionally, less than 1% (0.44%, n = 4) of respondents identified as American Indian or Alaska Native, 48% (n = 429) as Asian, 3% (n = 28) as Black or African American, 12% (n = 105) as Hispanic or Latinx, 4% (n = 38) as Middle Eastern, 25% (n = 222) as white, 7% (n = 64) as two or more races/ethnicities, 0.67% (n = 6) as other, and 0.55% (n = 5) chose not to respond. The survey was approved by UCLA's Institutional Review Board and administered online.

Materials

We developed a 47-question survey to investigate the prevalence and characteristics of digital flashcard use among college students. It encompassed three broad categories of interest:

1. How students make and/or obtain digital flashcards, and their reasons for doing so;
2. How students use digital flashcards to support their learning; and:

3. How students' practices and attitudes compare between digital and paper flashcards.

The survey was developed (a) in consultation with previous surveys addressing digital learning tools (e.g., Dornisch, 2013), (b) by adapting items from a prior survey on how and when students engage in self-testing with flashcards in general (Wissman et al., 2012),[1] (c) drawing on the experiences of the first author and anecdotes solicited from other undergraduates, and (d) considering the four evidence-based methods outlined in the Introduction. Prior to data collection, the questions were evaluated in a pilot test involving five UCLA undergraduate students, which informed minor adjustments to clarify wording and answer options. At the conclusion of the survey, we also included nine questions addressing general study and technology habits; the results from those questions can be found at this study's OSF repository.

The survey was programmed in Qualtrics (Qualtrics, Provo, UT) and could be accessed via any internet browser. The survey questions were ordered from general to specific, grouped by topic, and preceded by a series of demographic questions. A definition of "digital flashcards" was also presented at the start of the survey to provide relevant context: *"Digital flashcards are similar to paper flashcards. Such cards typically have a 'front' and 'back' wherein related information is presented. However, digital flashcards are created, stored, and used through digital means (e.g., accessed on a computer, phone, or tablet application, or on a website) rather than on physical cards"*. Respondents were permitted to decline answering any question except those that determine survey flow (e.g., respondents indicating that they had not ever used paper flashcards were automatically excluded from questions addressing the use of paper flashcards).

The majority of the survey questions involved multiple-choice (i.e., select the best-fitting answer option) or multiple-selection format (i.e., select all applicable options). Questions addressing the frequency of certain behaviours featured five answer options (*always*, *often*, *sometimes*, *rarely*, and *never*), whereas questions addressing beliefs or behaviours included answer choices specific to the question and, in most cases, the option to specify an "other" response (cf. Pan et al., 2020). The remainder of the questions were open-ended. These questions involved a numerical open-response format (i.e., input a number) or an open-text response format (i.e., respond in 1-2 sentences).

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[1] Wissman et al. (2012) did not specify which type (paper or digital) of flashcards students used in their original survey. However, because the default conception of flashcards is often of physical (i.e., paper) ones, we opted to use wording in our questions that would differentiate between the two types.

Scoring

Data from the multiple-choice and multiple-selection questions were tabulated within Qualtrics, with no further scoring necessary. Coding keys (each containing 10 to 20 categories) for the open-text response questions were generated by the first two authors from examination of themes from a subset of responses to each question. All open text-response questions were scored by two independent raters using coding keys. Because the coding keys were designed to allow raters to categorise each response with more than one code, interrater percentage agreement (see McHugh, 2012 for discussion on percentage agreement and chance agreement) was calculated using fractions in place of Cohen's kappa (which is not well-suited to accurately capture interrater reliability in cases wherein multiple answers can be coded for a single survey item; see Cohen, 1960). An interrater score of 0 indicated total agreement between raters (e.g., Rater 1: 6; Rater 2: 6), a score of 1 indicated total disagreement (e.g., Rater 1: 4; Rater 2: 5), and a fractional score indicated partial agreement (e.g., Rater 1: 4, 5, 7; Rater 2: 4, 6, 7 results in a score of 0.5). As the interrater percentage agreement for the first 200 responses for each question was acceptable (> 80%), all remaining responses were each coded by a single rater.

Procedure

Respondents accessed the survey link via the subject pool website (https://ucla.sona-systems.com/) and completed the survey on their personal laptop, computer, or other digital device. After giving consent to participate in the study, respondents were directed to answer each question as honestly as possible and then proceeded to the survey questions. There was no set time limit, but the average survey completion time was 20.9 minutes.[2]

Results and Discussion

We first report general findings for digital flashcard use among college students, followed by findings pertaining to the aforementioned three broad categories of interest, and then a set of exploratory correlational analyses. Major findings are summarised in the text, with further details included in accompanying tables and/or figures. In the tables, for questions marked with [m], respondents could select more than one answer option; for questions marked with [#], numeric responses were given; and questions marked with [f] were open-ended and were typically answered in 1-2 sentences. The order of the questions in the tables generally mirrors

[2]Average total time spent on the survey includes only the times of the participants who answered that they had used digital flashcards before (701) and excludes times that were greater than 2 hours (15) for a total of 686 times.

that of the actual survey with one prominent exception: For ease of exposition, questions that only targeted paper flashcard use, which duplicate those originally used in Wissman et al. (2012), are presented in the Appendix. Additionally, in several cases we report the total percentage of respondents that selected any of several response options, each of which is shown in the tables.

General Characteristics of Digital Flashcard Use Among College Students

As detailed in Table 2, digital flashcards are a widely known and remarkably popular learning tool among college students. Over three-quarters of respondents (n = 701, 77.8%) reported using digital flashcards, and of those respondents, well over half (63.9%) reported using digital flashcards at least sometimes during their learning activities. (Unless noted otherwise, the remainder of reported results involve the 701 respondents who answered that they have used digital flashcards.)

Although a variety of online flashcard programmes or services are used, the dominance of one platform, at least currently, is evident: Nearly all respondents (99.3%) had experience with Quizlet, and the vast majority (89.7%) reported most frequently using that platform. The next most popular flashcard platform, Anki, is far less commonly used (just 5.8% reported most frequently using it). Respondents offered many reasons for their choice of platform, with the three most common being ease of access (31.4%), familiarity (27.2%), and the availability of pre-made flashcard sets (21.0%). Digital flashcards are also most commonly used on a computer or laptop (70.1%), followed by smartphones (25.7%). Tablets were rarely used (4.0%).

The subject areas that digital flashcards are most frequently used for are science, history, social sciences, and foreign languages (see Table 2, Question 7 for rankings). In terms of content, digital flashcards are overwhelmingly used to learn vocabulary (93.9%), followed by key facts such as names or dates (74.6%) and concepts (70.2%). Using digital flashcards to learn more complex material (e.g., worked examples) is relatively rare (8.4%). Thus, replicating patterns that have been observed with paper flashcards (e.g., Wissman et al., 2012), digital flashcards tend to be used for relatively unsophisticated content.

Importantly, students tend to regard digital flashcards as helpful: An impressive 92.4% regard such flashcards as at least moderately helpful for studying or learning.

1. How College Students Make and/or Obtain Digital Flashcards

Creating and Obtaining Digital Flashcards

As detailed in Table 3, respondents more commonly reported using copy-and-paste functions (36.7%) or direct transcription (36.4%) to place information on (self-made) digital flashcards, rather than typing the information in their own words (26.8%). Pre-made digital flashcards were most commonly obtained via a web search (86.2%), with other, potentially more trustworthy sources of digital flashcards (e.g., "Friends studying for the same exam/class" or "Friends who have taken the class previously") endorsed less often (≤ 47.2%). Additionally, 55.9% of respondents reported not using or not making digital flashcards with images, which suggests that most users of digital flashcards are not using their multimedia capabilities to their full extent.

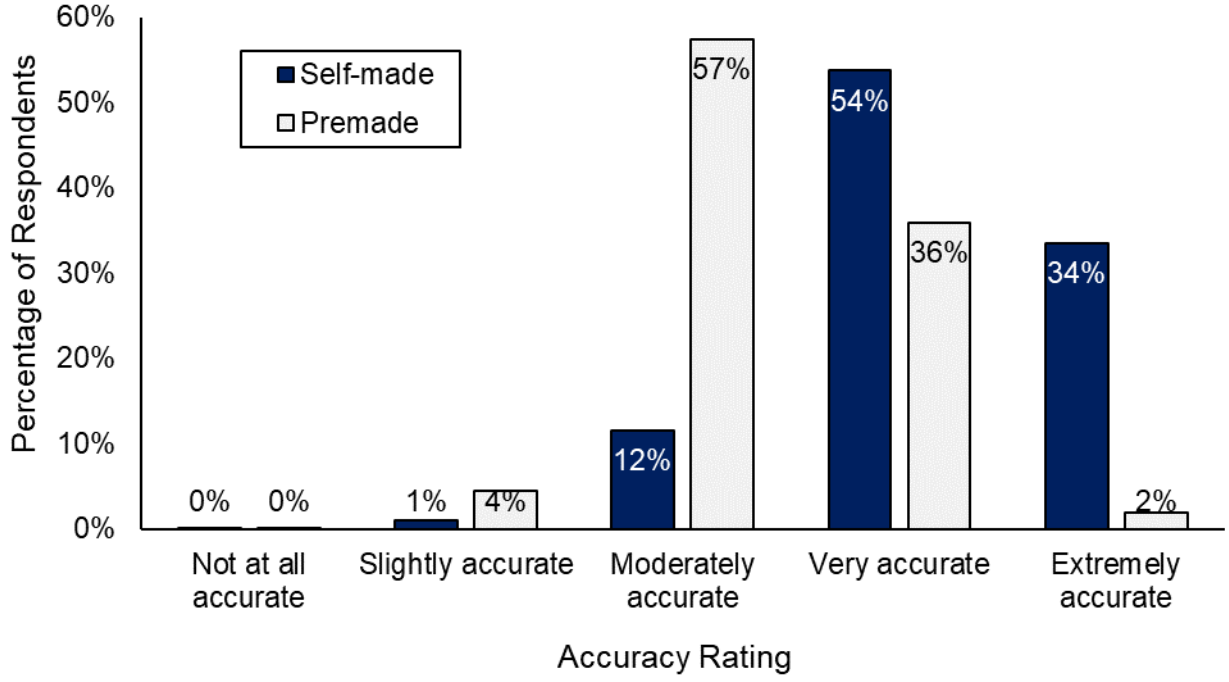
Preference for Pre-Made Versus Self-Made Digital Flashcards

Pre-made digital flashcards are more commonly used than self-made digital flashcards: Of the total time spent using digital flashcards, respondents reported spending, on average, 56.0% of their time using cards made by someone else and 44.0% of their time using self-made flashcards. Contrasting rationales were offered for the choice of one flashcard type over the other. Of the respondents that chose to use pre-made digital flashcards, most (81.3%) did so because they were easily available, followed closely by not having enough time to make their own digital flashcards (70.2%). Few indicated that they chose to use pre-made digital flashcards because they were of higher quality or more accurate than sets that they generated themselves (≤ 9.4%). Of those that chose to use self-made digital flashcards, however, most (76.2%) reported doing so because of the ability to control the information placed on the card, followed closely by the belief that the act of making flashcards served as a learning opportunity (66.0%). Moreover, 64.2% of self-made flashcard users did so because of the purported better accuracy or higher quality of such flashcards over pre-made versions that could be found online.

Overall, the forgoing results suggest that although college students tend to rely more on pre-made digital flashcards, they more frequently doubt their accuracy as compared to self-made flashcards. Indeed, as shown in Figure 1, when asked to rate the accuracy of pre-made and self-made digital flashcards, more respondents rated self-made flashcards as very or extremely accurate (87.3%), whereas fewer rated pre-made flashcards in the same way (38.0%).

Figure 1

Perceived Accuracy of Self-made and Pre-made Digital Flashcards



Note: Perceived accuracy of self-made and pre-made digital flashcards. Respondents gave separate accuracy ratings for self- and pre-made digital flashcards on a five-level scale.

2. How College Students Use Digital Flashcards

As detailed in Table 4, of the total time spent using digital flashcards, more respondents reported spending time practising recall or self-testing (58.5%) than studying, restudying, reading, or rereading (41.5%)—that is, using retrieval practice as opposed to less effective methods (Dunlosky et al., 2013; Pan & Bjork, 2022). As for *when* students use digital flashcard sets, few respondents reported spacing out their digital flashcard use throughout an academic term. Instead, digital flashcard use was closely tied to exam date: Roughly equal percentages of students reported that they gradually increase their use of digital flashcards as the exam approaches (28.4%), begin to use digital flashcards in the week of the exam (35.1%), or, perhaps most concerning, tend to use digital flashcards just in the day or two before an exam (29.7%). College students therefore do not appear to take advantage of opportunities to engage in distributed practice, or spacing, between their study sessions when using digital flashcards.

Although there was a nearly equal split between respondents who reported using digital

flashcards in one large set (49.2%) versus several smaller sets (50.8%), the mean reported number of cards in each set for the top three subject areas in which digital flashcards were used (as previously discussed) decreased by ranking but was still relatively high overall (mean of 76.8 cards for the first ranked subject, 55.5 for the second, and 45.1 for the third).

Use of Digital Flashcard Features

Most respondents (86.5%) reported at least occasional use of shuffle features that enable randomisation of the order in which flashcards appeared. Most respondents (≥ 84.0%) also reported using digital flashcard platforms that enabled them to change how many times a card appears by "starring" or marking it as "study later," and/or gave them control over when they could drop (i.e., remove from further study) cards. However, whereas most respondents did make use of "starring" or "study later" functions (63.9%), nearly half did not endorse using drop functions (49.8%). (It should be emphasised that the use and availability of "starring" or "study later" functions can occur independently of drop functions.) This result suggests that college students are (intentionally or inadvertently) taking advantage of spacing between specific items, and consequently receiving greater chances for additional practice by keeping all the cards in a deck during study sessions (i.e., students may be engaging in spacing between repetitions of a card, even if they are not taking advantage of spacing their study sessions). Further, even when digital flashcards were dropped, most respondents (69.0%) reported at least sometimes revisiting those flashcards.

Amount of Practice

The choice of the number of times to study each digital flashcard was most commonly made using a mixture of fluency (75.9%) and accuracy (74.5%). Respondents generally chose to stop studying when they had recalled the information on the flashcard correctly more than once (69.5%), but they also reported using retrieval fluency as a cue for when to stop studying with nearly the same frequency (66.2%). That students in the present study reported correctly recalling items more than once before dropping them contrasts with lab-based experiments which find that participants tend to drop items after one correct recall (e.g., Ariel & Karpicke, 2018; Dunlosky & Rawson, 2015; Karpicke, 2009; Kornell & Bjork, 2008), but align with the results of a prior survey on students' flashcard usage behaviors (Wissman et al., 2012).. The present results may thus have been influenced by differences in and out of the lab environments (see General Discussion). Regardless, the endorsement of both studying to criterion (most commonly 3 or 5 correct recalls of a given flashcard) and fluency cues demonstrates that although most

students are aware that more practice is helpful (particularly for self-testing), they also use potentially inaccurate metacognitive judgments based on their own feelings to regulate their learning.

Use of Correct Answer Feedback

Only 52.8% of respondents reported that they always check the correct answer on the back of their digital flashcards, which mirrors patterns observed with paper flashcards (Wissman et al., 2012). Over half of respondents also reported that they chose not to check because they were confident that the information that they had retrieved was accurate (53.5%), with feelings of fluency as the next most common reason (38.8% endorsing quick or easy retrieval as their rationale). These results raise the prospect that students may not be giving themselves the feedback necessary for effective self-regulated learning when using digital flashcards.

Using Digital Flashcards with Peers

As detailed in Table 5, although many respondents reported sharing their digital flashcards by sending them to classmates, friends, or study groups (≥ 38.5%), most rarely or do not ever *use* their digital flashcards with a study partner (65.9%). Of those who did report using them with a partner, the most common activity was taking turns quizzing each other (25.2%). Moreover, the use of digital flashcards with peers yielded relatively diverse assessments of impacts on motivation, difficulty, efficiency, and other characteristics (see Table 5, Question 4 for detailed results).

3. College students' practices and attitudes involving digital versus paper flashcards

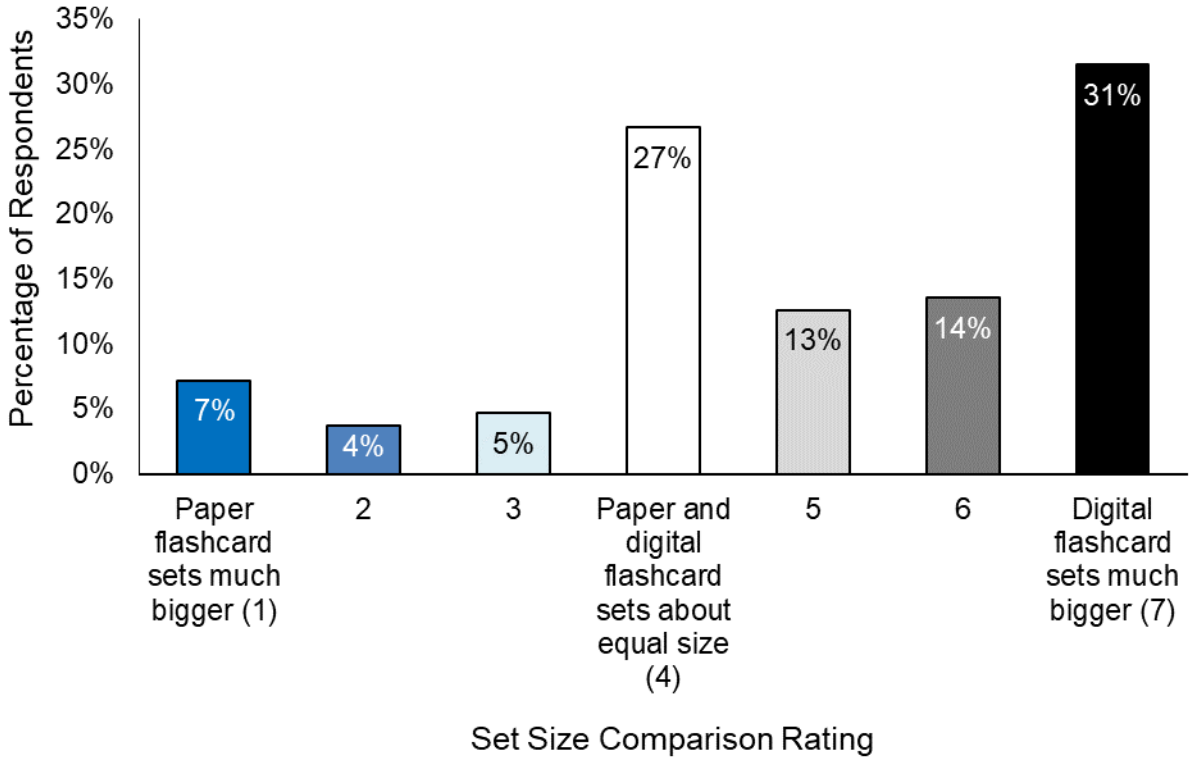
As displayed in Table 6, among users of digital flashcards, the vast majority, 91.6%, reported also using paper flashcards. All remaining results in this section are drawn from those 642 participants. As an average percentage of total study time, including activities that did not involve any flashcards, digital flashcards were far more frequently used (56.6%) than paper flashcards (24.9%). Respondents also expressed an overall preference for digital flashcards, with 60.1% preferring them over paper flashcards. The most commonly stated reason for preferring the digital medium was the convenience and ease of obtaining and using digital flashcards, although some respondents preferred handwriting and reported that it helped them learn the material more than digital flashcards did (for detailed results see Table 6, Question 3b).

As shown in Figure 2, respondents tended to use either the same size (26.6%) or much larger digital flashcard sets (31.5%) than paper ones. That result may speak to the convenience of using digital flashcards, and specifically the greater ease of creating and storing a large set of

digital flashcards than doing the same with paper versions. It also suggests that digital flashcards may facilitate greater use of within-session spacing. In addition, respondents reported that they were more likely to drop paper flashcards (35.5%) than digital flashcards (22.9%)—in fact, twice the number of respondents (16.8%) reported that they were much more likely to drop paper flashcards than digital flashcards than vice versa (8.9%). That finding further suggests that digital flashcard sets may be more conducive to achieving inter-item spacing within single study sessions.

Figure 2

Comparison of Digital and Paper Flashcard Set Sizes



Note: Comparison of digital and paper flashcard set sizes. Respondents rated the relative size of digital versus paper flashcard set on a seven-point scale.

With respect to the use of feedback, there was little difference in respondents' likelihood of checking the back of paper versus digital flashcards (see Table 6, Question 4). In fact, 70.9% of respondents reported that they were equally likely to check the backs of their digital and paper

flashcards. That high degree of equivalence suggests that the choice to use correct answer feedback in the context of flashcard learning is not heavily influenced by medium.

As detailed in the Appendix, respondents' answers to other questions addressing paper flashcard use—which were analogous to questions previously posed for digital flashcards—resembled their earlier answers (cf. Wissman et al., 2012). Responses to questions addressing types of learning activities, how many times a flashcard was used, and when to stop using a flashcard were all similar for paper and digital flashcards. Hence, students' cues and habits when engaging in self-regulated learning therefore do not appear to differ in any great way between mediums.

Exploratory Analyses

Why Students Choose Self-made Versus Pre-made Digital Flashcards

To further examine the surprising finding that most respondents chose to rely on pre-made digital flashcards despite tending to doubt the accuracy or quality of such cards, we conducted correlations that related respondents' frequency of using self- or pre-made digital flashcards with their reported reasons for doing so (Table 3, Questions 4 and 5). We first categorised particular answer choices in Question 5 into broad themes of interest as follows: (a) quality assurance (*I can control the information that goes on the card*, *The flashcard sets I make are more accurate than those found online*, and *The flashcard sets I make are higher-quality than those found online*) and (b) self-made advantages (*The act of making the flashcards helps me learn the material* and *The act of making the flashcards helps me know what I need to study*).

A series of correlations then related percentage of time using self-made digital flashcards with the number of answers chosen from each theme (a and b). Respondents who reported greater time spent using self-made digital flashcards endorsed more of the answer choices in the quality assurance theme, r (699) = .40, $p < .001$. Similarly, respondents who reported greater time spent using self-made digital flashcards endorsed more of the answer choices in the self-made advantages theme, r (699) = .43, $p < .001$. Endorsement of answer choices from these two themes was also correlated, r (699) = .37, $p < .001$. That is, those who selected more of the choices in the quality assurance theme also tended to select more of the choices in the self-made advantages theme. It is therefore likely that participants who considered the quality of the digital flashcards they made themselves were also attuned to the potential benefits of the action of making them, and vice versa.

Using the same process as with Question 6, we categorised particular answer choices in

Question 5 into the following broad themes: (a) quality assurance (*I trust the information on pre-made flashcard sets*, *Pre-made flashcard sets are higher quality than those I can self-generate*, and *Pre-made flashcard sets are more accurate than those I can self-generate*) and (b) efficiency (*I don't have the time to make my own flashcard sets* and *Pre-made flashcard sets are easily available*). As expected, respondents who reported more time using self-made digital flashcards endorsed fewer answer choices in the quality assurance theme, r (699) = -.23, $p < .001$, and fewer answer choices in the efficiency theme, r (699) = -.37, $p < .001$. Endorsement of these two themes was also correlated, r (699) = .20, $p < .001$. In other words, respondents who reported less belief in pre-made sets' accuracy and less concern about the ease of generating flashcard sets, as compared to accessing pre-made sets, used pre-made flashcard sets less frequently.

Rates of Self-Testing with Digital Versus Paper Flashcards

To examine whether students engage in similar habits when using digital and paper flashcards, we correlated participants' percentage of study time self-testing using digital flashcards (Table 4, Question 1) with percentage of time self-testing with paper flashcards (Appendix, Question 1). Frequency of self-testing across these two mediums was significantly correlated such that participants who reported higher rates of self-testing when using digital flashcards also reported higher rates of self-testing when using paper flashcards, r (640) = .53, $p < .001$. This finding adds further support to the conclusion that neither medium encourages greater self-testing than the other, and that respondents' study habits remain relatively stable across both paper and digital flashcard use.

Grade Point Average

Finally, to test for possible relationships between students' self-reported grade point average (GPA) and their digital flashcard usage patterns, we also completed three sets of exploratory correlational analyses. These analyses were conducted on the 658 participants who provided such data (those who chose not to report their GPA, did not have an established GPA yet, or did not use a 4.0 scale were excluded from these analyses). None of the correlations were statistically significant: Participants who reported using digital flashcards for more types of information (Table 2, Question 7) did not report significantly higher GPAs, $p = .35$, GPA was not significantly correlated with the frequency of using particular methods to put information on digital flashcards (Table 3, Question 1), ps $\geq .16$, and GPA was not significantly correlated with greater use of self-made (or pre-made) digital flashcards (Table 3, Question 4), $p = .64$. Hence, digital flashcard usage patterns do not appear to be predictive of academic performance, at least

as indexed by GPA. It should be noted, however, that GPA can be affected by factors unrelated to digital flashcard use, including the type and difficulty of coursework, and that GPA is a less precise measure of learning than, for example, specific course grades. In addition, many respondents reported that they used digital flashcards to study for standardised tests, which do not have any bearing on GPA.

General Discussion

The foregoing survey investigated the use of digital flashcards during self-regulated learning among college students. A host of interesting insights emerged. First, digital flashcards are remarkably popular. The vast majority of students report using them. Second, digital flashcards are overwhelmingly regarded as being beneficial for studying or learning. However, when it comes to using digital flashcards to their fullest potential, at least as informed by evidence-based learning research, our results reveal a mixed picture. Among today's college students, although some usage patterns show greater adherence to learning science-based principles and practices than others, in other cases, students tend to use flashcards in highly suboptimal ways. We next consider these usage patterns in light of learning practices that are highlighted in the *desirable difficulties* framework and supported by evidence-based learning research.

Do Digital Flashcard Usage Patterns Align with Evidence-Based Learning Practices?

One of the most promising results in our survey was the finding that college students commonly use digital flashcards to engage in retrieval practice. Hence, it appears that researcher and instructor recommendations to use flashcards for the purposes of beneficial self-testing are being heeded. That result is in line with the general popularity of retrieval practice as a learning strategy (e.g., Hartwig & Dunlosky, 2012; Pan et al., 2020), although students tend to regard self-testing as a method of assessing one's own learning as opposed to enhancing it (Pan & Bjork, 2022). Less promisingly, a sizeable minority of college students report using digital flashcards to engage in non-retrieval-based strategies (e.g., rereading) that have dubious pedagogical value (Callender & McDaniel, 2009; Dunlosky et al., 2013).

When using digital flashcards to engage in retrieval practice, many students do not consistently take advantage of correct answer feedback. Instead, they use a variety of factors to decide whether or not to do so, some of which are evidence-based (e.g., the prior number of correct retrievals; Kornell & Bjork, 2008), and others of which are not (e.g., retrieval speed and fluency; Benjamin et al., 1998). That failure to consistently use feedback likely deprives students

of learning opportunities. It should be noted, however, that feedback in the case of successful retrieval from memory may not always be necessary (Pashler et al., 2005), and retrieval practice is generally effective at enhancing learning even in the absence of correct answer feedback (Roediger & Karpicke, 2006). Nevertheless, the benefits of retrieval practice are often augmented by feedback (Rowland, 2014), and researcher recommendations to use retrieval practice are typically accompanied by the advice to use feedback.

Observed usage patterns for digital flashcards are mixed with respect to spacing. Consistent with the well-established pattern of cramming for exams (e.g., McIntyre & Munson, 2008), college students do not often begin using their digital flashcard sets until close to the exam date. Such cramming likely deprives students of valuable time that could have been used to engage in beneficial spacing between study sessions (Sobel et al., 2010). Indeed, the vast majority of college students did not endorse a strategy of "spacing out" the use of digital flashcards throughout an academic term, contrary to evidence-based recommendations to do so. More promisingly, they tended to endorse the use of starring functions more than dropping functions, which implies the occurrence of inter-item spacing during learning sessions. It was also generally common for students to endorse revisiting individual flashcards more than once, which can be a further opportunity for inter-item spacing to occur. It should be noted, however, that some flashcard programs allow dropping items from study after one correct retrieval attempt, which may inadvertently encourage less effective learning strategies (see Table 1 of Dunlosky & O'Brien, 2020 for a comparison of several digital flashcard programs).

Another concerning aspect of college students' digital flashcard practices is an apparent reliance on pre-made flashcard sets even given doubts about the accuracy or quality of those sets. This pattern, which was relatively widespread, suggests that college students engage in an *ease-accuracy trade-off* when deciding to make or obtain digital flashcards—that is, they are willing to take the risk that the digital flashcards that they use are suboptimal in exchange for the convenience of quickly obtaining and readying them for use. That ease-accuracy trade-off assumes that pre-made flashcard sets can be incomplete or inaccurate, and that students' self-made flashcard sets may be of higher quality than the ones that they can obtain online. Even if those assumptions are not met, however, a reliance on pre-made digital flashcards likely deprives students of the benefits of generating their own content (cf. Slamecka & Graf, 1978; Bertsch et al., 2007). Recent work has demonstrated that engaging in generation does indeed augment the benefits of learning with digital flashcards (Authors, 2021). Interestingly, some of our survey

respondents seemed aware of such potential benefits (given that the endorsement of statements related to the benefits of generating flashcards was correlated with use of self-made flashcards during study).

It is also notable that many college students endorsed the use of shuffle functions with digital flashcards. Doing so can be a way to introduce not just inter-item spacing but also interleaving of items—that is, the intermixing of different concepts, categories, or other types of materials during learning (Kang, 2016). The interleaving of closely related concepts when studying, or *interleaved practice*, has shown promise at enhancing learning and memory in such educationally-relevant domains as mathematics (e.g., Rohrer, 2012) and physics (e.g., Samani & Pan, 2021). However, the optimal approach with which materials are interleaved has yet to be fully established (particularly for such domains as language learning; e.g., Pan, Lovelett, et al., 2019), and the evidence base in favour of interleaved practice is less established than that for the other aforementioned effective learning strategies.

How Do Usage Patterns Compare for Digital Versus Paper Flashcards?

Although college students can use digital flashcards and paper flashcards in similar ways (see Appendix), our findings reveal that college students view digital flashcards as distinct from paper flashcards: Our sample indicated a clear preference for digital over paper flashcards, citing the convenience of creating digital flashcards and the ease of transporting and accessing these digital flashcards as primary reasons for their preference for digital flashcards over paper ones. Indeed, our results imply a shift in college students' learning habits away from paper to digital flashcards. That shift is in line with educational trends showing an increasing move towards digital modalities (National Center for Education Statistics, 2019), accelerated by changes in education due to the COVID-19 pandemic.

With respect to evidence-based learning strategies, some of the usage patterns for digital flashcards resemble those reported for paper flashcards (e.g., Wissman et al., 2012), including the relative popularity of retrieval practice, the underutilisation of feedback, and frequent cramming before exams. However, perhaps because of the ease of creation, storage, and portability of digital flashcards, college students tend to make larger digital flashcard sets than paper flashcard sets, which may yield more opportunities for inter-item spacing than with paper flashcards. In addition, given the greater accessibility of pre-made digital flashcards, it seems likely that student users of digital flashcards engage less frequently in the productive generation of flashcard content than with paper flashcards (which are commonly created by methodically

writing down to-be-learned information).

A unique characteristic of digital flashcards, as compared to paper flashcards, is that many platforms include extra features that may enhance learning. For instance, nearly one-quarter of college students reported using digital flashcard platforms that had complete or near total control over when a flashcard was removed from further study. Designers of these platforms (e.g., Anki) seem aware that students do not always make optimal decisions during self-regulated study, and therefore offer features (e.g., spaced repetitions) that make such decisions for them. Hence, the use of such platforms (as compared to using paper flashcards or entirely self-directed digital flashcard services) may actually aid students seeking to improve their learning, and especially for students that may not have ample support or knowledge about evidence-based learning techniques. Moreover, digital flashcard algorithms (e.g., Colbran et al., 2018; Edge et al., 2012) are not susceptible to overconfidence or influenced by retrieval fluency, and may therefore, at times, make more sophisticated learning decisions than students potentially might make. Similarly, adaptive schedules of practice (e.g., Mettler et al., 2016) can account for variations in strength of learning across different items using, for example, response time in addition to accuracy to maximise learning based on ongoing performance.

Students could potentially even learn valuable learning practices from such features, and the customisation offered by many flashcard services (e.g., altering the spacing between repetitions) could also provide a means to explore the effectiveness of different learning strategies and associated metacognitive judgments.

Alternatively, however, such features may take away crucial aspects of what makes self-regulated learning "self-regulated" and encourage students to approach learning sessions on "autopilot," resulting in a dependence on digital flashcard platforms to make learning strategy decisions for them. Overreliance on digital flashcard platforms may therefore harm learners in some cases. It is also possible that students who are not yet as skilled in self-regulated learning may need more scaffolding and rely more on algorithmic digital flashcard platforms, giving them a chance to see demonstrations of effective learning strategies in practice. Careful consideration of *which* platform to use, in addition to whether to use a paper or digital medium, is thus necessary when evaluating how best to address learning goals.

Survey Limitations

We note three potential limitations of the foregoing survey. First, the survey was administered in the fall and winter of 2020 during the COVID-19 pandemic. Most students were

receiving fully remote or hybrid instruction, which may have increased their reliance on online resources. While the pandemic likely accelerated the existing trend toward using more digital tools, the results reported here should nevertheless be interpreted in the context of pandemic-era instructional practices. Additionally, the reported results feature responses only from UCLA students and the sample was dominated by Quizlet and/or Anki users. It is possible that somewhat different results may have emerged, for example, if community college students had been sampled or if Quizlet users had been excluded from participation. Finally, the use of multiple-choice or multiple-selection formats (as opposed to open-ended response formats) for most questions may have led to greater suggestibility in how students responded. However, the provided responses in the present survey likely reflect the range of students' possible responses given that a majority of the multiple-choice and multiple-selection questions and their possible responses were based on Wissman et al.'s (2012) open-response survey questions and actual student responses.

Directions for Future Research

The foregoing survey provides vital normative data that can serve as theoretical and practical grounding for future explorations of digital flashcard features or patterns of use. Areas for further research include exploring how digital flashcards could be designed to foster better metacognition (i.e., using algorithmically controlled vs. user-controlled digital flashcard platforms), if training students about how to effectively use digital flashcards (i.e., instructions to always check the back of the flashcards after retrieval) could help optimise the use of digital flashcards, investigating the environments in which digital flashcards are used (cf. Imundo et al., 2020), whether creating and/or using digital flashcards collaboratively to make and/or use flashcards (which our survey data imply is currently relatively rare) could confer additional benefits beyond working alone, and any significant associations of digital flashcard use with academic performance (although our analyses involving GPA did not detect any such patterns). Additionally, our results suggest that students primarily use flashcards to learn relatively low-level (e.g., vocabulary) as compared to high-level (e.g., worked examples) content (cf. Pan et al., 2018); future studies could explore if digital flashcards are indeed only useful for learning such basic content, or if there are benefits to incorporating higher-level information in digital flashcard sets (perhaps by taking advantage of multimedia presentation features). Future research could also explore instructors' incorporation of digital flashcards into their classroom practices, which include offering students instructor-created flashcard sets, creating study guides in the

form of flashcards, or the use of auxiliary features of flashcard platforms (e.g., flashcard-based games) as class activities.

Finally, as digital flashcard technologies continue to evolve, it will be important for researchers to keep abreast of new developments and investigate their impacts on student learning. Going forward, it is likely that digital flashcards will continue to be an important strategy for college students when they engage in self-regulated learning. Hence, research on the subject stands to remain important and relevant for years to come.

Acknowledgments

This research was supported by a scholarship from the Undergraduate Research Scholars Program at UCLA and the Kroner Family Endowed Fellowship at UCSD awarded to I.Z. The authors wish to thank Shanae Wong and Emily Marquez for their assistance with coding survey responses. We are also grateful to Steve Reiss and Noreen Webb for their advice on data analysis procedures. The authors also thank members of the Bjork Learning and Forgetting Laboratory at UCLA and Naomi Eisenberger for their thoughtful suggestions and discussions throughout the development of this project. Special thanks as well to John Dunlosky and an anonymous reviewer for helpful comments on an earlier version of this manuscript.

Declaration of Interests

The authors report there are no competing interests to declare.

Data Availability Statement

Data and materials for this study are archived at the Open Science Framework at: https://osf.io/5g4ur/

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Appendix

Survey Questions Addressing Paper Flashcard Use

1. When using paper flashcards, what percentage of time are you engaging in the following activities? Note: These numbers should add up to 100% (n = 642) [#]

Activity	Mean Percentage of Time
practising recall (self-testing)	62.1%
studying, restudying, reading, or rereading	37.9%

2. How often do you shuffle your paper flashcard sets? That is, change the order in which those cards are viewed/used? (n = 642)

Response	Frequency
always	30.4%
often	36.1%
sometimes	19.5%
rarely	11.2%
never	2.8%
Response left blank	9.2%

3. Imagine that you are studying with a set of paper flashcards. Which of the following would influence how many times you studied a card? (n = 642) [m]

Response	Frequency
How easily you could remember the card	77.6%
How long you planned to study that day	21.2%
How many times you could correctly recall the card	79.9%
The importance of the particular card	51.1%
Other	0.0%

4. Imagine that you are studying with a set of paper flashcards. How do you decide when you have studied a paper flashcard sufficiently? (n = 642) [m]

Response	Frequency
I felt like I immediately knew the correct answer	71.3%
I recalled the content on the flashcard correctly one time	8.4%
I recalled the content on the flashcard correctly more than once	71.2%
I recalled the content on the flashcard quickly	53.0%
I understood the information	56.2%
Other	0.2%

5. In general, how many times do you successfully recall the information on the back of a paper flashcard before you drop the paper flashcard from study? (Assuming that you drop cards; if not, please indicate that you do not drop cards by typing "N/A".) Note: Your answer needs to be a number. (n = 642) [#]

Response	Frequency*
1	2.2%
2	9.2%
2.5**	0.5%

3	26.5%
3.5**	0.2%
4	5.8%
5	18.4%
5.5**	0.2%
6	1.2%
7	2.2%
8	2.2%
10	5.0%
N/A	20.2%

6. How often do you go back to the paper flashcards that you dropped? (n = 642)

Response	Frequency
always	12.9%
often	21.0%
sometimes	39.3%
rarely	18.1%
never	5.9%
Response left blank	2.8%

Note. (*) Ten (1.6%) responses were not included here because respondents listed percentages. Another 31 (4.8%) responses were not included because respondents listed a number between 15 and 99. (**) Some respondents gave ranges (e.g., "2-3 times"), which were coded as the median of the range.

Table 1

Potential Impacts of Common Digital Flashcard Features on Student Learning

Feature	Potential Impact on Learning
Ability to ‘flip’ flashcards	Opportunities for retrieval practice, correct answer feedback
Dropping functions	Reduces opportunities for spacing
Making one's own flashcards	Opportunities for generation
Multimedia presentation	Opportunities for dual coding
Required checking of feedback	Opportunities for correct answer feedback
Required revisiting of cards	Opportunities for spacing
Shuffling capability	Opportunities for varied practice
Starring functions	Opportunities for spacing, additional learning of specific cards
Using pre-made flashcards	Reduces opportunities for generation

Table 2

General Characteristics of Digital Flashcard Use

1. Prior to taking this survey, have you ever heard of digital flashcards before? (n = 901)

Response	Frequency
Yes	85.0%
No	15.0%

2. Have you ever used digital flashcards before? (n = 901)

Response	Frequency
Yes	77.8%
No	22.2%

3. In any of your studying or learning activities, do you use digital flashcards? How often do you use them? (n = 701)

Response	Frequency
always	2.1%
often	18.0%
sometimes	43.8%
rarely	34.2%
never	1.9%

4. Which, if any, of these digital flashcard services have you used? (n = 701) [m]

Service	Frequency
Anki	15.1%
Brainscape	4.6%
Cram	0.7%
Quizlet	99.3%
Studyblue	5.6%
Study Stack	2.3%
Other	1.0%

5a. What digital flashcard service do you use the most? (n = 701) [f]

Service	Frequency
Anki	5.8%
Brainscape	0.1%
Quizlet	0.0%
StudyBlue	89.7%
Other	0.3%
Response left blank	2.0%

5b. What is the primary reason for your use of this digital flashcard service as opposed to other services? Please answer in 1-2 sentences. (n = 701) [f]

Response Category	Frequency
platform is free	6.8%
platform is popular / peers or friends use same platform	16.8%
instructors use platform	6.4%
platform is the only one participant is familiar with (e.g., used or heard of)	27.2%
ease of access (e.g., platform is user friendly, easy to use, convenient/accessible)	31.4%
platform features	13.6%

sharing	2.6%
images	0.1%
sound	0.1%
games	2.7%
participant is most comfortable/familiar with this platform	13.1%
platform has pre-made sets	21.0%
platform is easier to use/cheaper than paper flashcards	1.6%
using the platform has led to positive results in the past	3.4%
platform allows you to test yourself	6.8%
saves paper/environmentally friendly	1.4%
Other	7.7%
Response left blank	1.9%

6. Of the time you spend using digital flashcards, what percentage of time do you use them on the following devices? Please put 0 if you do not use digital flashcards on that device. Note: These numbers should add up to 100%. (n = 701) [#]

Device	Mean Percent of Time
Computer/laptop	70.1%
Phone	25.7%
Tablet	4.0%
Other	0.2%

7. What subject areas do you tend to use digital flashcards for? Please put the subject areas in order of how often you use digital flashcards for them, from most to least often. (n = 701)

	Ranking (1 to 3, most to least often)		
Subject Area	1st	2nd	3rd
Math	0.1%	5.6%	7.3%
Science	39.4%	21.5%	17.3%
History	12.6%	25.1%	28.0%
English composition / writing	2.4%	4.4%	5.8%
Foreign languages	21.7%	18.0%	16.7%
Social sciences	22.0%	24.1%	21.3%
Performing arts	0.0%	0.1%	0.6%
Other	1.4%	0.9%	2.3%

8. What type of information is typically on your digital flashcards? (n = 701) [m]

Information Type	Frequency
Concepts (e.g., equilibrium in science, interdependence in history)	70.2%
Equations/formulas	40.9%
Key facts (dates, names, etc.)	74.6%
Practice questions	37.8%
Vocabulary	93.9%
Worked examples	8.4%
Other	1.1%

8. In your opinion, how helpful are digital flashcards for your studying/learning? (n = 701)

Response	Frequency
not at all helpful	0.4%
slightly helpful	7.1%
moderately helpful	31.1%

very helpful	46.1%
extremely helpful	15.3%

Table 3

How Pre-Made and Self-Made Digital Flashcards Are Created or Obtained, and Why

1. Please indicate how often you use the following methods to place information on your digital flashcards. Note: These numbers should add up to 100%. (n = 701) [#]

Method	Mean Percentage of Time
Copy and paste	36.7%
Directly transcribe (e.g., type out word for word)	36.4%
Type up in my own words	26.8%

2. If you use pre-made digital flashcard sets, where do they come from? (n = 701) [m]

Response	Frequency
Friends studying for the same exam/class	47.2%
Friends who have taken the class previously	31.2%
Web search	86.2%
Other	4.0%
I do not use pre-made digital flashcard sets	5.1%

3. Do you ever put images on your digital flashcards, or use digital flashcards that have images on them? (n = 701)

Response	Frequency
Yes, I make my own images	0.4%
Yes, I use pre-made images from other sources	31.5%
Yes, I use both my own and pre-made	8.6%
No	55.9%
The digital flashcard platform I use does not support images	3.6%

4. Of self-made and pre-made digital flashcard sets, what percentage of the time do you use each type of flashcards? Note: These numbers should add up to 100%. (n = 701) [#]

Digital Flashcard Type	Mean Percentage of Time
Pre-made	56.0%
Self-made	44.0%

5. If you choose to use pre-made digital flashcard sets rather than make your own digital flashcard sets, why do you do so? (n = 701) [m]

Motive	Frequency
I don't have the time to make my own flashcard sets	70.2%
I trust the information on pre-made flashcard sets	37.4%
Pre-made flashcard sets are easily available	81.3%
Pre-made flashcard sets are higher quality	9.4%
Pre-made flashcard sets are more accurate	7.4%
Pre-made flashcard sets contain practice questions	34.7%
Other	2.3%
I do not use pre-made digital flashcards	5.7%

6. If you choose to make your own digital flashcards, rather than use pre-made digital flashcard sets, why do you do so? (n = 701) [m]

Motive	Frequency
I can control the information that goes on the card	76.2%
I enjoy making my own flashcard sets	16.3%

The act of making flashcards helps me learn the material	66.0%
The act of making flashcards helps me know what to study	44.8%
The flashcard sets I make are more accurate	40.5%
The flashcard sets I make are higher quality	23.7%
There are no pre-made flashcard sets for the material I need	37.8%
Other	2.0%
I do not make my own digital flashcards	10.4%

Table 4

How Digital Flashcards Are Used

1. When using digital flashcards, what percentage of time are you engaging in the following activities? Note: These numbers should add up to 100% (n = 701) [#]

Activity	Mean Percentage of Time
practising recall (self-testing)	58.5%
studying, restudying, reading, or rereading	41.5%

2. Which of the following best describes how you tend to use digital flashcards? (*n* = 701)

Response	Frequency
Spaced out (i.e., spread out) throughout the quarter	6.8%
A day or two before the exam	29.7%
Increasing gradually in frequency as the exam approaches	28.4%
The week of the exam	35.1%

3. In general, do you prefer to study digital flashcards as one big set or do you prefer to study digital flashcards in a series of smaller sets? (*n* = 701)

Response	Frequency
I prefer to study one big set	49.2%
I prefer to study several smaller sets	50.8%

4. How many cards, on average, are in your digital flashcard sets for the [top three subjects that you use digital flashcards for]? (*n* = 701) [#]

Ranking	Mean Number of Cards
1st	76.8
2nd	55.5
3rd	45.1

5. How often do you shuffle your digital flashcard sets? That is, change the order in which those cards are viewed/used? (*n* = 701)

Response	Frequency
always	31.8%
often	33.2%
sometimes	21.4%
rarely	9.3%
never	4.3%

6. When you study with digital flashcards, which of the following items best describes how the decision to stop studying a card occurs? (*n* = 701)

Response	Frequency
The digital flashcard programme has complete or most control.	23.0%
You (the learner) and the programme have equal.	35.4%
You have complete or most.	41.7%

7. Do you use any digital flashcard features that allow you to change how many times a card appears or when to stop studying a card (i.e., “starring” or “study later” functions)? (*n* = 701)

Response	Frequency
Yes, I have used such functions when available	63.9%

No, I have not used such functions when available	26.1%
No, such functions have not been available	10.0%

8. Do you use any "drop" (remove from further study) functions when studying with digital flashcards? (*n* = 701)

Response	Frequency
Yes, I have used such functions when available	34.2%
No, I have not used such functions when available	49.8%
No, such functions have not been available	15.8%
Response left blank	0.1%

9. How often do you go back to the digital flashcards that you dropped or did not mark for further study? (*n* = 701)

Response	Frequency
always	8.6%
often	17.4%
sometimes	43.1%
rarely	21.7%
never	7.1%
response left blank	2.1%

10. Imagine that you are learning with a set of digital flashcards. Which of the following would influence how many times you studied a card? (*n* = 701) [m]

Response	Frequency
How easily you could remember the card	75.9%
How long you planned to study that day	17.0%
How many times you could correctly recall the card	74.5%
The importance of the particular card	45.6%
Other	0.1%

11. Imagine that you are learning with a set of digital flashcards. How do you decide when you have studied a digital flashcard sufficiently and DO NOT need to study it again? (*n* = 701) [m]

Response	Frequency
I felt like I immediately knew the correct answer	66.2%
I recalled the content on the flashcard correctly one time	7.1%
I recalled the content on the flashcard correctly more than once	69.5%
I recalled the content on the flashcard quickly	47.2%
I understood the information	55.2%
Other	0.7%

12. In general, how many times do you successfully recall the information on the "back" of a DIGITAL flashcard before you drop the DIGITAL flashcard from study? (Note: your answer needs to be a number or "N/A".) (n = 701) [#]

Response	Frequency*
0	0.1%
1	0.6%
2	7.8%
2.5**	0.3%
3	23.7%
3.5**	0.1%
4	6.7%
5	18.0%
5.5**	0.1%
6	1.1%
7	2.1%
8	1.7%
10	5.4%
N/A	25.1%

13. When learning with digital flashcards, how often do you check whether the information that you recalled is correct by looking at the "back" of the flashcard? (n = 701)

Response	Frequency
always	52.8%
often	36.1%
sometimes	9.8%
rarely	1.1%
never	0.1%

14. If you ever choose NOT to check if the information you recalled is correct by looking at the back of the digital flashcard, what contributes to your decision? (n = 701) [m]

Response	Frequency
I was confident that the information I retrieved was accurate	53.5%
I knew I was going to go back and study that information again	9.1%
I retrieved the information quickly	18.0%
I retrieved the information easily	20.8%
Other	0.4%
I always check	45.6%

Note. (*) Ten (1.43%) responses were not included because respondents listed percentages, and another 36 (5.14%) responses were not included because respondents listed a number between 15 and 200. (**) Some respondents gave ranges (e.g., "2-3 times"), which were coded as the median of the range.

Table 5

Using Digital Flashcards with Peers

1. Do you share your digital flashcards in any of the following ways? (n = 701) [m]

Response	Frequency
Send to classmates	38.5%
Send to friends	47.9%
Share with study groups	41.1%
Make available for public use	24.1%
Other	0.6%
I do not share my digital flashcards	33.7%

2. How often do you use digital flashcards with a study partner or friend? (n = 701)

Response	Frequency
always	1.3%
often	9.6%
sometimes	23.3%
rarely	23.7%
never	42.2%

3. If you do use digital flashcards with a study partner or friend, how do you do so? Please answer in 1-2 sentences. If you DO NOT use digital flashcards with a study partner or friend, please type "N/A." (n = 701) [f]

Response Category	Frequency
Take turns quizzing each other	25.2%
Test themselves simultaneously (i.e., both look at same side)	3.9%
Make or create the cards together (or split the work)	4.3%
Send the cards to each other or share the cards and/or links	15.7%
Study or review the cards simultaneously or together	5.4%
Cross-check information with each other's sets	1.9%
Compare errors and/or explain errors to each other	0.9%
N/A	55.3%
Other	0.6%
Response left blank	0.3%

4. How is your experience of using digital flashcards alone different from your experience using them with a partner? (Assuming you do use flashcards with a partner; if not, please write "I do not use digital flashcards with a partner.") Please answer in 1-2 sentences. (n = 701) [f]

Response Category	Frequency
Partner provides accountability for errors	6.7%
Partner provides greater focus (accountability)	1.6%
Respondent is more motivated to study with a partner	3.6%
Respondent has greater difficulty focusing with a partner	2.7%
Respondent experiences greater pressure with a partner	1.6%
More mental energy required with a partner	0.1%
More time spent per card with a partner	0.1%
Making digital flashcards with a partner is efficient/easier	1.3%

Respondent can proceed at own pace when alone	7.4%
Using digital flashcards alone is more efficient	4.3%
Respondent self-tests when alone instead of testing each other	2.9%
Respondent answers silently when alone instead of aloud	4.4%
Testing is easier with a partner	1.3%
Partner provides more, different, or missing information	3.4%
Partner generates more discussion (rather than pure recall)	5.6%
Partner helps figure out how to remember a card	1.0%
More helpful to use digital flashcards with a partner	3.1%
I do not use digital flashcards with a partner.	55.5%
No difference with a partner vs. alone	2.7%
Other	6.4%
Response left blank	0.9%

Table 6

Practices and Attitudes Involving Digital Versus Paper Flashcards

1. Do you use, or have you ever used, paper flashcards? (n = 701)

Response	Frequency
Yes	91.6%
No	8.4%

2. Out of all of your learning activities, what percentage involves using digital flashcards? What percentage involves using paper flashcards? Please provide your best estimate. Note: These numbers do not necessarily need to add to 100. (n = 701)[#]

Activity	Mean Percentage of Time
digital flashcards	56.6%
paper flashcards	24.9%

3a. Do you prefer paper or digital flashcards? (n = 642) [f]

Response	Frequency
Paper flashcards	25.7%
Digital flashcards	60.1%
Equal preference	1.4%
Preference depends on situation	4.3%
Response left blank	3.3%

3b. Why do you prefer one over the other? Please explain in 1-2 sentences. (n = 642) [f]

Response Category	Frequency
Digital flashcards are easier to search through	1.9%
Digital flashcards are easier to manage, keep track of, and/or organize	11.8%
Digital flashcards are easier, faster, cheaper, or more convenient to make	25.9%
Digital flashcards have unlimited storage and/or take up less space	6.1%
Digital flashcards are more convenient or almost always accessible	37.9%
Digital flashcards are easier to edit	2.6%
Typing is easier than, faster than, or preferable to handwriting	6.2%
Digital flashcards allow copy-paste functions	2.0%
Digital flashcards are more effective	0.3%
Digital flashcards have pre-made sets available (easier and faster to find)	8.4%
Digital flashcards provide more options or features (e.g., games)	11.7%
Some digital flashcards have pre-determined spaced repetition algorithms	0.6%
Paper flashcards show visual representation of learning (e.g., stack sizes)	1.1%
Easier to draw on paper flashcards	2.8%
Prefer handwriting, which helps with retention	19.6%
Paper flashcards are more effective ("learn more")	3.7%
Prefer looking at paper over looking at a screen	2.6%
Prefer using something physical	5.8%
Do not know how to make digital flashcards	0.2%
Paper flashcards are wasteful	8.4%
No reason given (only stated preference)	1.9%
Other	10.4%
Response left blank	9.2%

4. Please rate how likely you are to check the back of the flashcards when using paper flashcards compared to using digital flashcards. (n = 642)

Rating	Frequency
I am much more likely to check the back of the flashcard when using paper. (1)	6.1%
2	3.7%
3	6.9%
I am equally likely to check the back of paper and digital flashcards. (4)	70.9%
5	5.6%
6	2.6%
I am much more likely to check the back of the flashcard when using digital. (7)	4.2%

5. Please rate how likely you are to drop paper flashcards relative to digital flashcards. (n = 642)

Rating	Frequency
I am much more likely to drop paper than digital flashcards. (1)	16.8%
2	9.5%
3	9.2%
I am equally likely to drop paper and digital flashcards. (4)	41.6%
5	7.2%
6	6.9%
I am much more likely to drop digital than paper flashcards. (7)	8.9%

6. Please rate how often you access paper flashcards compared to digital flashcards in the following situations. (n = 642)

Rating	During class	While studying	While traveling or commuting
I access paper flashcards much (1)	7.9%	8.9%	5.6%
2	6.5%	6.2%	5.0%
3	4.4%	4.4%	2.2%
I access both types of flashcards equally (4)	22.6%	16.0%	9.8%
5	6.7%	10.1%	5.9%
6	13.4%	18.1%	15.1%
I access digital flashcards much more (7)	38.5%	36.3%	56.4%

Figure Captions

Figure 1 Perceived accuracy of self-made and pre-made digital flashcards. Respondents gave separate accuracy ratings for self- and pre-made digital flashcards on a five-level scale.

Figure 2 Comparison of digital and paper flashcard set sizes. Respondents rated the relative size of digital versus paper flashcards on a seven-point scale.